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HYDRAULIC ANALYSIS OF WATER DISTRIBUTION SYSTEMS BY MEANS OF AN ELECTRIC NETWORK ANALYZER.*

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The Hydraulic Problem. In the design of new water distribution systems or reinforcements to existing systems, it is necessary to select the sizes of the pipes by trial and check them by estimating the pressure drops due to domestic and fire drafts. For a given system, several critical points will emerge during the study at which it appears desirable to investigate the pressure when drawing both domestic and fire flows. Each of these critical points will have its minimum allowable pressure determined by the height of the buildings in the district. If the static pressure is fixed, as in an existing system, each critical point will have its allowable pressure-drop under the worst loading conditions for that point. If the static pressure is not fixed, as for an entirely new system, it may be determined by considering jointly the permissible pressure upon plumbing systems and the maximum pressure-drops to all the critical points. The allowable pressure-drop to each critical point will be determined by both the permissible minimum pressure and the elevation of the point.

An estimate of the pressure drop in a single pipe of known size and characteristics may readily be made, if the discharge is known, by using whichever of the many friction formulas seems to suit the conditions best. These formulas can all be reduced to the general form

$$h = c\,Q^x \qquad (1)$$

where h is the loss in energy head
Q is the discharge
x is an exponent varying from about 1.7 to 2.0, depending upon the formula used
and c is a constant for the pipe depending upon the size, length, and roughness.

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For laminar flow, the exponent x is 1.0. For turbulent flow at high velocity, the value of x approaches 2.0. Both conditions may obtain in a distribution system under a single combination of loads with low velocities in pipes far removed from the fire and high velocities in close proximity to the fire. For this reason, and also because losses in bends and changes in velocity head must be neglected in practical solutions of distribution system problems, the use of a single value of x for all the pipes such as the round number 2.0 seems called for. The exponent for the Hazen-Williams formula is 1.85. In order to demonstrate that the method developed in this paper is general, one of the examples which follows has been worked with this formula. If x is 2.0 the equation corresponds with the Chézy or Weisbach formula. If it is desired to use Kutter's roughness factor n, and Manning's value of the Chézy coefficient C, the constant in the foot-pound-second system is

$$c = 4.66\frac{n^2 l}{d^{5.33}} \qquad (2)$$

Here l is the length of pipe and d is the diameter. If the discharge is expressed in gallons per minute, the value of c from equation (2) must be divided by 450^2. The values of c may be computed for all of the pipes or elements in a distribution system or they may be readily estimated by means of a flow chart. The pressure drop, or loss of head, for each pipe may then be calculated readily if the discharge is known; but the discharge through each pipe for a given draft from the system is not easily computed, and the calculation of pressure losses is thus greatly complicated.

Existing Methods of Solution. Of the existing practical methods for solving compound-pipe problems, the "equivalent-pipe" method is the only one which offers an explicit and a reasonably accurate solution. This method consists of substituting for the system a single pipe which, for a given pressure-drop, will deliver the same flow as the system. Two or more pipes operating in series can be converted to an equivalent pipe by adding the head losses for a given flow and determining from equation (1) the value of c corresponding to the flow and the sum of the head losses. Two or more pipes operating in parallel between two points and without intermediate junctions can be converted to an equivalent pipe by adding the discharges for a given head loss between junction points and finding from equation (1) the value of c corresponding to the head loss and the sum of the discharges. Since c is a function of both length and diameter [see equation (2)] it is immaterial what length is assumed for the equivalent pipe provided the corresponding value of the diameter is taken. If computations are made analytically instead of by means of charts, it is not necessary to assume, either length or diameter for the equivalent pipe, the value of c being all that is needed.

For extremely simple systems, this process can be continued until an equivalent pipe is found for the whole system, after which, for a given loading, the pressure drops can be readily found. Unfortunately, very few

actual systems are sufficiently simple to permit the application of this process without approximations. If two parallel pipes operating between two points are connected at intermediate points by a cross pipe, the method cannot be used; for, in this case, neither the head loss nor the discharge for the cross pipe is known for a given head loss through the parallel pipes. In order to use the equivalent-pipe method, an assumption must be made as to the discharge or head loss in the cross pipe, or else one of its junction points must be assumed to be at one of the ends of the parallel pipes. The error introduced by such an assumption is not readily estimated and may be large.

Another method which offers an accurate solution but is not explicit may be called the "trial-and-error" method. In this method, a division of flow is assumed at each of the joints, and the corresponding head losses are computed for the trial flows thus set for each pipe. If the head loss between any two junction points is not the same by all routes, the trial division of flow is in error and another trial must be made. For some systems, a solution of the problem can be obtained by this method in a not unreasonable length of time. If there are many flow-division points, however, as in a grid system, it is obvious that a satisfactory balance of flows may never be reached by the trial-and-error method. The equivalent-pipe and trial-and-error methods may often be used together to advantage.

Another method used to give an approximate solution is to assume for a fire that the pressure gradient in the system in the direction towards the fire is about the same at points equi-distant from the fire. This is equivalent to assuming that the flow towards the fire at any radial distance from the fire is divided among the pipes at this distance in accordance with their capacities. Such a solution will seldom be close to and may give results quite far from the truth.

Mathematical Analysis. Consider the simple case of flow between two points through two parallel pipes. For a given discharge through the system there are five unknowns, the discharge and head loss through each of the branches and the head loss through the system as a whole. There are two equations, applications of equation (1), relating head to discharge; one for each branch. There is one equation relating to the division of flow, and one equation for each branch equating the head loss to the total for the system. This makes five equations in all, which are sufficient for a solution.

In a simple case of flow through two pipes in series, for a given discharge, there are again five unknowns which are the same as before. For a solution, there are again two head-discharge equations, there are two equations equating the discharge in the elements to the discharge through the system, and there is one equation relating to the division of head.

If now a single pipe is added to either system without dividing an existing pipe, two more unknowns are added, the head and discharge for the new pipe. There are also two more equations available for solution: the head-discharge equation for the new pipe and another equation relating to division of flow or division of head.

If a new pipe is added which divides one existing pipe into two parts, that is, provides another joint, it is equivalent to adding two new pipes and four unknowns. If a new pipe is added which divides two existing pipes into two parts each, or provides two new joints, it is equivalent to the addition of three new pipes and six more unknowns. For each unknown added there is, however, an equation available.

Any system, therefore, is susceptible of solution analytically, but the number of equations that must be solved simultaneously increases rapidly with the number of pipes added.

The equations that may be written are of three types and arise from three laws which may be stated as follows:

1. The algebraic sum of the rates of discharge towards any junction point is zero.
2. The algebraic sum of the head losses around any closed circuit is zero.
3. For any pipe or system of pipes the head loss is directly proportional to some power of the discharge. For practical solutions it is assumed that this power is constant and the same for all the pipes and for the system as a whole.

The Hydraulic and Electric Analogy. The first two of the laws just given correspond with Kirchhoff's laws for electric circuits which may be stated as follows:

1. The algebraic sum of the currents flowing into any junction point is zero.
2. The algebraic sum of the voltage drops around any closed circuit is equal to zero.

The third hydraulic law is analogous to Ohm's law for direct-current circuits in which the voltage drop in any element or system is directly proportional to the current. The analogy is inexact, however, because the exponent of the current in Ohm's law is one, and the exponent of the discharge in the hydraulic friction formulas is greater than one. The analogy is better if the equations are written as follows:

Hydraulic friction $h = c\,Q^x$ (1)

Electric friction $V = k\,I^x$ (3)

where V is the potential drop

I is the electric current

and since from Ohm's law $V = RI$

the electrical resistance, R, is a function of the current, i.e.,

$$R = k\,I^{x-1} \tag{4}$$

This analogy between hydraulic flow and electric currents suggests the use of an electric calculating board or network analyzer* for the solution of hydraulic problems. These boards have been used for some years for solving similar problems relating to the distribution of electricity.

*Hazen, Schurig and Gardner—The M. I. T. Network Analyzer—Trans. A. I. E. E., July, 1930, p. 1102.

Figure 1 illustrates the analogy between hydraulic and electrical distribution systems. Each pipe or element in the hydraulic system can be represented by a resistor in a similar electric network. The reservoir or other source of water supply can be represented by a battery or other source of electric current. The resistors at the load points in the electric system are simply means for regulating the current at the points to correspond with the water loads.

Solution of Hydraulic Equations by Electrical Network. As has been stated, the equations that must be satisfied by the flow in any hydraulic network can be readily written. The difficulty occurs when their solution is

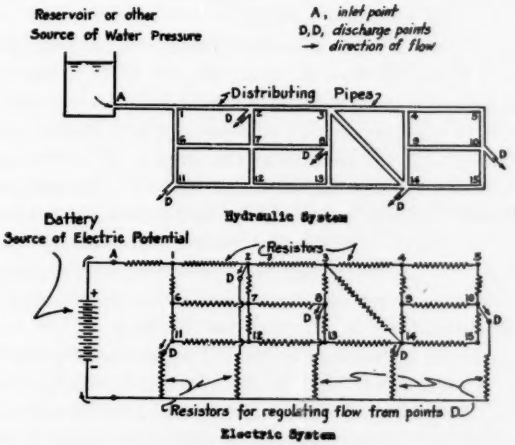

FIG. 1.—ILLUSTRATING THE ANALOGY BETWEEN THE HYDRAULIC AND ELECTRIC SYSTEMS. From Bachelor's Thesis by Collins and Jones, 1933.

attempted. If a model is constructed to which the same equations apply, and on which their solutions can be read directly, these solutions evidently are valid for the original problem. In the method here presented the model is an electrical network. Since the first two laws of hydraulic flow are identical with the two Kirchhoff laws of electric circuits, the equations written by the application of these laws to similar hydraulic and electric networks will be identical except for the scale ratios. Although the third law of hydraulic flow, relating lost head to discharge, differs somewhat from Ohm's law, the latter can be modified to agree with the hydraulic law by always adjusting the electrical resistance of an element so that it satisfies equation (4). Postulating this adjustment, the equations written by the application of the third law to the two similar systems will also be identical except for scale ratios.

The only problem then is to make the two networks similar. Similarity in the configuration and number of elements suffices for similarity with respect to the first or junction law, and is necessary for similarity with respect to the second or loop law. Similarity with respect to the second and third laws requires in addition that the elements have similar pressure-discharge laws, which is effected by making the electrical resistance of each element satisfy equation (4) in which k is related by a scale ratio to c of equation (1).

With these conditions for similarity satisfied, the equations of the model are identical with the equations of the hydraulic network, except for the constant scale ratios. Therefore, the values of the variables observed in the model when multiplied by the constant scale ratios are solutions of the equations of the hydraulic network.

Description of the M. I. T. Network Analyzer. As utilized in the solution of problems of hydraulic flow in pipes, the M. I. T. network analyzer is primarily an assortment of resistors so arranged that they can be readily interconnected in the proper way to represent any desired pipe network. There are several ranges of resistance, the units of each range being adjustable between wide limits by dial switches. In general large-resistance units serve to represent pipes in which the friction loss is great, small-resistance units to represent pipes in which the friction loss is small. Large resistors are also suitable for adjusting load flows as will be seen subsequently. The M. I. T. network analyzer includes sufficient resistance units to represent pipe and load elements up to a total of one hundred.

Interconnection of resistors is effected by means of a bus and flexible-lead scheme. An electrical "bus" is merely a conductor used as a junction or terminal to which circuits can be connected. Each of numerous buses in the network analyzer has many outlets, consisting of simple tapered sockets, to which resistors can be readily connected, using flexible leads terminated with tapered plugs. Each bus then corresponds to an hydraulic junction and each resistance unit to a pipe line. Thus by means of the resistances and their interconnections, any hydraulic network within the scope of the analyzer can be represented as a network of electrical resistances.

For solving a problem, a source of electric pressure and current, as well as convenient methods for making measurements, must be available. Any reasonably steady source of direct-current of suitable current capacity and voltage can be used. A battery is preferable, because the steadiness of its voltage facilitates rapid adjustments. Measurements are made by inserting standard direct-current instruments into the network. Current or electric flow is measured with an ammeter which can be connected in series with a resistance element by merely inserting a plug in a socket. Voltage or electric head is measured with a voltmeter which can be connected between any two points in the network by inserting two plugs. Standard instruments of suitable type are available for this purpose.

As the size of network that can be studied on the network analyzer is limited by the number of resistors available, a list of these resistors is given in Table 1.

TABLE 1.— TABULATION OF RESISTORS IN THE M. I. T. NETWORK ANALYZER

Resistor Number.	Maximum Resistance—Ohms.	Minimum Step—Ohms.	Quantity Available.	Maximum Rating.
R_1 to R_{25}	10	0.1	25	4 amperes
R_{26} to R_{60}	100	1.0	35	2 amperes
R_{61} to R_{90}	4 000	4.0	30	1 ampere
R_{91} to R_{100}	20 000	200.0	10	200 volts

Of these units the first three are suitable for representing pipe elements and the last two for adjusting load flows. It is seen therefore that the network analyzer provides means for representing a relatively complicated hydraulic network and for establishing and measuring flow and pressure conditions therein.

Adaptation of Hydraulic Problem to Analyzer. As presented for study, an hydraulic network consists of pipes of various sizes and lengths, fed at one or more points from reservoirs or pumps and from which various domestic and fire loads are drawn. A typical problem involves the determination of the pressures at various points for predetermined domestic and fire loads. In what follows the various detailed steps of solving such a problem on the analyzer are described and illustrated by application to a very simple example.

It is assumed that a map of the system is furnished showing all relevant hydraulic details such as the pipe sizes and lengths, the location of reservoirs and other sources of supply, the location of loads, and valves, and the elevations of all significant points; and that for each condition to be studied, sufficient additional information pertaining to applied heads, loads, etc., is given to fix the flow uniquely throughout the network. It is also necessary to assume a pipe-friction formula and a roughness factor.

When the system is other than very simple, it is necessary to "boil down" or simplify the actual system to a skeleton system both to make a study practicable and to bring the number of elements within the scope of the analyzer. In this process, the guiding principles are the retention of the more significant elements and the replacement of groups of minor elements by single equivalent elements wherever practicable. Many minor elements of any city system must of necessity be omitted from the skeleton system. It is probably safe to assume that the omission of elements leads to pessimistic results, i.e., that for a given flow a greater pressure drop will occur between supply and load when any element is omitted than when it is present. Loads, too, must be "lumped" so that the water taken over a certain area appears as a concentrated flow at some point in the simplified network. In making these simplifications it is undoubtedly important to maintain greater fidelity to the actual network in the immediate vicinity of arge loads than in parts of the system remote from them. As a result of

these simplifications a new map can be prepared which shows the relevant details of the simplified system and which serves as the basis for the electrical study.

The next step is the calculation of the constant c of equation (1) for all of the pipe elements of the simplified system. Figure 2 shows a simple example which will be used to illustrate the method of procedure. In this example, the exponent x is taken as 2.00 and the value of c is calculated from equation (2) using $n=0.0127$, but adapted to gallons-per-minute instead of cubic-feet-per-second units for Q. Placing these quantities in equation (2):

$$c=0.263\ l \text{ for } Q \text{ in cubic feet per second.}$$

For Q in gallons per minute:

$$c=1.30 \times 10^{-6} l \tag{5}$$

TABLE 2. — QUANTITIES RELATING TO SIMPLE ILLUSTRATIVE EXAMPLE.

Element		Length—Ft.	c	Estimates.				$k=\frac{a}{b^2}c$
From.	To.			Flow Q. g.p.m.	Lost Head. h—Ft.	$\frac{h}{Q}$	R First Approx.	
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	2	1 500	1.95×10^{-3}	100	19.5	0.195	97.5	1 950
3	4	1 500	1.95×10^{-3}	100	19.5	0.195	97.5	1 950
1	3	500	0.65×10^{-3}	100	6.5	0.065	32.5	650
2	4	500	0.65×10^{-3}	100	6.5	0.065	32.5	650
3	2	1 000	1.30×10^{-3}	0	....	.....	....	1 300
1	4	....	....	200	....	.....	....	....

Element		Balance Conditions Electrical Quantities.		Solution of Hydraulic Problem.			
		Potential Difference—Volts.	Current—Amperes.	Flow—g.p.m.		Lost Head, Ft.	
From.	To.			Meas.	Calc.	Meas.	Calc.
		(9)	(10)	(11)	(12)	(13)	(14)
1	2	3.09	0.039	78	78.2	12.3	11.9
3	4	3.07	0.039	78	78.2	12.3	11.9
1	3	2.47	0.061	122	121.8	9.8	9.6
2	4	2.45	0.061	122	121.8	9.8	9.6
3	2	0.60	0.022	44	43.6	2.4	2.5
1	4	5.56	0.100	200	200.0	22.2	21.6

The third column of Table 2 gives the values of c for the various elements of the example as calculated from equation (5). This step in the procedure being completed and illustrated, the next step, the selection of the hydraulic electric scale ratios, will be considered. The interrelations between the scales are easily determined as follows:

Let
$$V=a\,h \tag{6}$$
$$I=b\,Q \tag{7}$$

where a is the scale ratio of potential drop to head
and b in the scale ratio of current to discharge.

Equation (3) is solved for k, and V and I from equations (6) and (7) are substituted in the result, giving

$$k = \frac{a}{b^x} \cdot \frac{h}{Q^x} \tag{8}$$

Since, from equation (1), $\frac{h}{Q^x} = c$, equation (8) may be written

$$k = \frac{a}{b^x} c \tag{9}$$

It is evident that, of the three scale factors relating V and h, I and Q, and k and c respectively, two can be chosen arbitrarily; this fixes the third.

The choice of scales is limited primarily by two factors: the errors caused by the insertion of measuring instruments; and the size and current capacity of the available resistors.

In the first, both ammeters and voltmeters are important. Thus, the insertion of an ammeter has an effect equivalent to increasing the friction factor of the element in which it measures the flow. The effect of a voltmeter is analogous to shunting a small pipe between the two points at which the voltmeter is connected. However, by keeping the scales within suitable ranges, and selecting suitable instruments, which are of standard and rugged types, these errors are made negligible.

Considering the second factor, it is readily seen that it is desirable that a single resistor represent a pipe element. Hence the value of resistance given by $k I^{x-1}$ in equation (4) should be within the range of an available resistor. To secure precision in setting the resistor, the resistance should be a reasonably large fraction of the maximum setting, but sufficiently less than this to allow for some adjustment in the balancing process described subsequently. The limitation due to the current capacity of the resistors usually affects only the voltage that can be applied to the load resistors.

One additional consideration relating to the voltage scale merits discussion, since it affects particularly the ease of manipulation in the experimental work. As set up for the solution of an hydraulic problem, the electric circuit consists of two types of elements: the resistors representing network elements or pipes; and those used to control the discharge at the loads. As will be seen subsequently, the electrical solution is affected by a method of successive approximations in which the resistor corresponding to each pipe element is adjusted in turn so that equation (4) is satisfied for that element. This process necessarily alters the flow distribution within the network and will also materially alter the load discharges due to the variation of voltage at the discharge points, unless the voltage drops across these load resistors are made large compared to the drops occurring within the network. Hydraulically this corresponds to taking the datum plane for head at such a low level that the static head at any point in the network is large compared to the differences in head within the network. As the

maximum voltage conveniently available is about 230 volts and as the load resistors are designed for 230 volts maximum, it is desirable to select a voltage scale such that the maximum pressure-drop corresponds to a voltage drop that is a small fraction of 200 volts. The limitation due to errors caused by instruments is usually entirely compatible with this criterion.

In choosing scales, the general procedure involves estimating the flow, usually very roughly, and from this the lost head in each of the various elements. The quotient af the lost head by the flow is then determined. This quotient is proportional to the resistance, which can be seen by substituting equations (8) and (7) in equation (4) thus:

$$R = k\ I^{x-1} = \frac{a}{b^x}\ \frac{h}{Q^x}\ \cdot\ b^{x-1}\ Q^{x-1} = \frac{a}{b}\ \cdot\ \frac{h}{Q} \tag{10}$$

The range of $\frac{h}{Q}$ is noted and a value of $\frac{a}{b}$ determined that will give convenient values of R. A value of a is then chosen that gives a suitable value to the total voltage drop through the network, and the value of b calculated therefrom. If the voltage drops and currents in individual elements then are large enough to make the ammeter drop and voltmeter current, respectively, negligible in comparison, the scales are suitable. If not, the results indicate clearly in what direction the scales should be altered.

Applying this procedure to the example, it is seen that a value for $\frac{a}{b}$ of 500 makes the maximum resistance, which is undoubtedly estimated too high, slightly under 100 ohms. The minimum resistance is 32.5 ohms. Both values are convenient for the 100-ohm units, which are usually found suitable for the average elements. As the system is simple, a small voltage across the entire network, such as 5 volts, suffices to obscure the ammeter drop, and a trial value of $a = 0.25$ volts per foot is tentatively selected. This fixes b at 5×10^{-4} amperes per gallon per minute. With these scales, the minimum voltage drop and current are about $6.5 \times 0.25 = 1.6$ volts and $100 \times 5 \times 10^{-4} = 0.050$ amperes, respectively. A standard type 0.100-ampere ammeter can be obtained having a voltage drop of 1 millivolt at full scale. This is negligible in comparison with 1.6 volts. A standard 3.0-volt voltmeter drawing 0.0005 amperes at 1.6 volts is also available, this current being negligible in comparison with 0.050 amperes. The scales chosen are therefore suitable and are adopted.

Having selected the scales, the values of resistance for the first approximation are calculated, together with the values of k for the various pipes. These are given in columns 7 and 8, respectively, of Table 2.

An electrical diagram of connections is next made resembling the map of the hydraulic system, which shows the numbers of the resistors and buses, and their connections. Figure 2 shows this diagram for the example.

Resistor R6 is used merely to adjust the current flow to the specified value.

When the connections indicated on the connection diagram have been made on the network analyzer, the system is ready for the balancing operation.

Balancing the Network. As shown by equation (4) the resistance of each element must be a given function of the current flowing through it if the electrical network is to represent the hydraulic network correctly. In general the estimated flows and, therefore, the initial settings of the resistors are incorrect. The process of bringing these quantities into agreement by successive approximations is called a "balancing process."

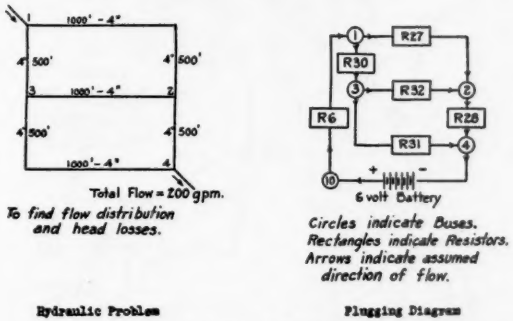

FIG. 2.— FIRST EXAMPLE.
From Bachelor's Thesis by Collins and Jones, 1933.

A preliminary step in the balancing process consists of setting the load resistors so that they draw the required currents, preferably beginning with the largest load. Assuming properly chosen scales, these loads will require only minor subsequent readjustment.

In the balancing process proper, a unit is selected for the first adjustment which appears to contribute largely to the pressure drop. Its resistance is adjusted until equation (4) is satisfied. Alternatively, the adjustment can be checked by a voltmeter using equation (3). The only important elements, as judged by their contributions to the pressure drop, are similarly adjusted in turn. As each new adjustment alters flow throughout the network, it throws the previously adjusted elements out of balance again. However, by traversing the network a few times, three traverses usually sufficing, it is found that all of the elements are in acceptable adjustment and the balancing process is complete. The electrical conditions correctly represent the hydraulic conditions, and results can be read immediately.

Since readings of current and voltage are quickly and easily made it is desirable to take a complete set for purposes of check. If these readings satisfy Kirchhoff's junction-current and loop-voltage laws within experimental error the likelihood of mistakes in readings or connections is remote.

The results obtained after balancing the simple network are shown in columns 9 and 10 of Table 2.

Interpretation of Results. By means of the hydraulic-electric conversion factors, the voltage drops are readily changed to differences in head and the currents to hydraulic flow.

Applying equations (6) and (7) to the data of columns 9 and 10 of Table 2, the flow and lost head as shown in columns 11 and 13 are obtained.

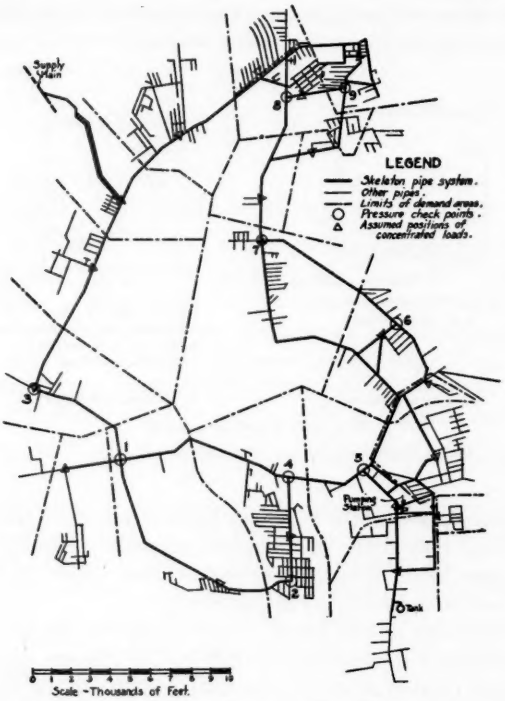

FIG. 3.— WATER DISTRIBUTION SYSTEM, WARWICK, R. I.

These may be compared with the values in columns 12 and 14 which were obtained from an analytical solution. These results constitute the solution of the problem.

Solution of a Practical Hydraulic Problem. The computation of pressure gradients in the water distribution system of Warwick, R. I., for two fire-load conditions is presented in order to illustrate the application of electric network analyzers to the solution of practical problems. This system was designed by Fay, Spofford & Thorndike, Consulting Engineers of Boston, and the computations presented here were made by J. D. Collins and Edward L. Jones in 1933 as a part of a Bachelor's thesis.

It should be noted that the Warwick distribution system is a rather simple one and may be analyzed readily by the trial-and-error method. The choice of this system for developing and illustrating the electric network method of analysis was satisfactory, but no attempt should be made to compare the time required and cost of solution by the two methods on the basis of this problem. The proper field of usefulness of the electric-

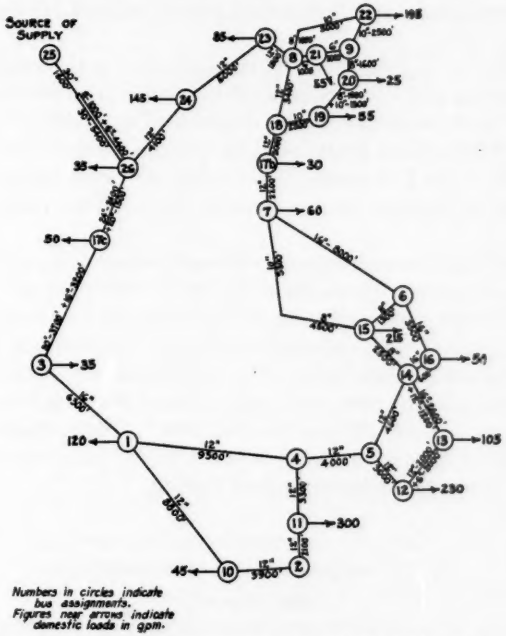

FIG. 4.— WATER DISTRIBUTION SYSTEM, WARWICK, R. I.
Simplified Skeleton System.

network analyzer is in the solution of networks which cannot be readily analyzed by the trial-and-error or equivalent-pipe methods.

Figure 3 is a map of the system to scale. Warwick receives its water from the city of Providence at one point, as indicated on the map. To simplify this problem, the pressure at the source was assumed constant and at an elevation of 225 ft. above sea level. The small district fed by the booster pump in the lower right-hand corner of the map was omitted; also for the sake of simplicity. The system was divided into districts whose boundaries are indicated on the map by dash-dot lines. A skeleton system was assumed made up of all the main lines, which are indicated by heavy lines on the map. The domestic load was estimated for each district and was assumed to be concentrated at a point on the skeleton network.

Figure 4 shows the skeleton system with the sizes and lengths of the pipes. Each junction point is designated by the number of the bus on the electric network analyzer which was assigned to that junction. The domestic load for each district in gallons per minute is indicated by the figure at the end of the arrow at the assumed load point.

In order to select the resistors for the elements, it was first necessary to compute the constants and select scales. In this problem, the Hazen-Williams pipe friction formula was used with a value of 110 for the Chézy coefficient C.

The value of the exponent x in equation (1) for the Hazen-Williams friction formula is 1.85. The value of the constant c per 1 000 feet of pipe of each size in the skeleton system was determined by dividing the head loss taken from Williams and Hazen's tables for a given discharge by that discharge raised to the 1.85 power. Two values of c were obtained for each pipe size and the average used as the unit value. These values are shown in Table 3.

The constant c for each element was next computed by multiplying the length of the element in thousands of feet by the unit value of c. Since some of the elements are compound pipes, it was necessary, for these elements, to compute the values of c for the equivalent pipes. The resulting values of the pipe constants are indicated as c_o in the ninth column of Table 4.

The scales selected were 2 feet per volt and 20 000 gallons per minute per ampere, so that a is 0.5 and b is 0.05×10^{-3}. The corresponding value of the constant k from equation (9) is $45.3 \times 10^{6}\, c$. The values of k for each element are shown in the last column of Table 4.

TABLE 3.— COMPUTATION OF CONSTANTS.

Water Distribution System — Warwick, R. I.

Unit Values of c.

Pipe Diam. In.	Q g.p.m.	h_m Ft. per 1000 Ft.	c_m	Q g.p.m.	h_m Ft. per 1000 Ft.	c_m	c_m Average.
6	695	52.4	$.291 \times 10^{-3}$	1 390	190.5	$.289 \times 10^{-3}$	$.290 \times 10^{-3}$
8	695	12.7	.0705	1 390	45.4	.0688	.0695
10	695	4.27	.0237	2 085	32.5	.0232	.0235
12	1 390	6.4	.00969	2 780	22.6	.00962	.00965
16	2 085	3.32	.00237	6 950	30.9	.00238	.00238
20	2 085	1.12	.00080	6 950	10.4	.00080	.00080
24	3 475	1.18	.000333	13 900	15.4	.000335	.000334
30	3 475	0.399	.000112	13 900	5.2	.000113	.000113

NOTE: Hazen-Williams Formula used: $v = 1.318\, CR^{0.63} S^{0.54}$

with $C = 110$

Corresponding head-discharge equation: $h = c\, Q^{1.85}$

Tables were used in finding h.

Here C is a constant R is the hydraulic radius and S is the hydraulic slope.

TABLE 4.— COMPUTATION OF CONSTANTS.
Water Distribution System — Warwick, R. I.

Scales selected: 20 000 gallons per minute per ampere; 2 feet per volt.
Values of c and k for Skeleton System.

ELEMENT.		Pipe Diam. In.	Length thousands of Ft.	$c \times 10^3$	Pipe Diam.- In.	Length thousands of Ft.	$c \times 10^3$	$c_0 \times 10^3$	k
From.	To.								
25	26	30	1.6	0.000181	..	5.4	0.00058	0.00076	34.4
26	17c	24	2.4	.000802	20	1.5	.0012	.0020	90.6
17c	3	20	3.7	.00296	16	3.2	.00761	.0106	480.0
3	1	16	6.3	.0150	..	..	.....	.0150	680.0
1	4	12	9.3	.0897	..	..	.....	.0897	4060.0
4	11	12	3.3	.0319	..	..	.....	.0319	1445.0
11	2	12	2.1	.0203	..	..	.....	.0203	920.0
1	10	12	8.8	.0850	..	..	.....	.0850	3850.0
10	2	12	3.9	.0376	..	..	.....	.0376	1706.0
4	5	12	4.0	.0386	..	..	.....	.0386	1748.0
5	12	12	3.0	.0290	..	..	.....	.0290	1314.0
5	14	12	4.5	.0434	..	..	.....	.0434	1965.0
14	13	16	2.6	.00618	12	1.2	0.0116	.0178	806.0
12	13	12	2.0	.0193	6	2.0	.580	.600	27200.0
26	24	12	4.1	.0396	..	..	.....	.0396	1794.0
24	23	12	5.0	.0482	..	..	.....	.0482	2185.0
23	8	12	1.5	.0145	..	..	.....	.0145	656.0
8	18	12	3.4	.0328	..	..	.....	.0328	1488.0
8	21	6	1.0	.290	..	..	.....	.290	13150.0
8	22	10	5.0	.1185	8	1.0	0.0695	.188	8520.0
21	9	6	2.0	.58	..	..	.....	.58	26300.0
9	22	10	2.5	.0587	..	..	.....	.0587	2660.0
18	19	10	2.2	.0517	..	..	.....	.0517	2345.0
19	20	8	1.5	.104	10	1.3	0.0306	.135	6110.0
9	20	8	1.6	.111	..	..	.....	.111	5030.0
18	17b	12	2.0	.0193	..	..	.....	.0193	875.0
17b	7	12	2.2	.0212	..	..	.....	.0212	961.0
7	6	16	8.0	.0190	..	..	.....	.0190	862.0
7	15	10	5.3	.1245	8	4.5	0.313	.438	19700.0
6	15	8	1.2	.0834	..	..	.....	.0834	3780.0
15	14	8	2.5	.174	..	..	.....	.174	7880.0
16	14	16	0.6	.00143	..	..	.....	.00143	64.8
6	16	16	3.5	.00833	..	..	.....	.00833	378.0

NOTE: $k = \dfrac{0.5}{(0.05 \times 10^{-3})^{1.85}} c = 45.3 \times 10^6 \, c$

Now for any discharge through an element it is possible to compute the resistance required for that element from equation (4). Hence the water loads in gallons per minute including the fire load were converted to amperes and the whole flow distributed approximately between the elements, as

indicated in Table 5. The resistance corresponding to the flow assumed for each element was then computed from equation (4) which for the Hazen-Williams formula is $R = k\ I^{0.85}$

Resistors were next selected which had maximum values somewhat in excess of the estimated resistances. The resistor numbers are shown in the last column of Table 5.

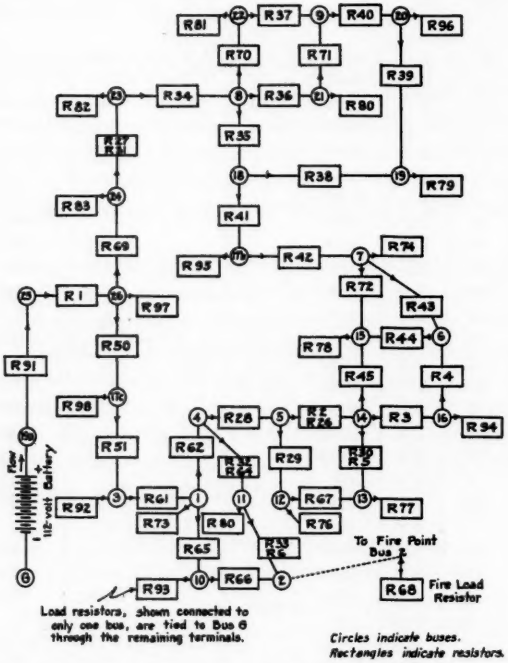

FIG. 5.— WATER DISTRIBUTION SYSTEM, WARWICK, R. I.
Plugging Diagram for 1 500 g.p.m. fire at Point 2.

Figure 5 is a plugging diagram for a fire load of 1 500 g.p.m., at point 2. The pipe elements are represented by the selected resistors and the source of supply by a 112-volt battery. The network analyzer was connected in accordance with this diagram.

The first step in the balancing operation was the adjustment of the load resistances to give the proper load currents. The load currents were checked and corrected from time to time during the balancing operation.

The next step in the procedure was the adjustment of each resistor in turn until equation (4) was satisfied. Balance 1 in Table 6 shows the readings obtained for each element during the first balancing operation. Balance 2 and 3 show the readings obtained for each element during the

TABLE 5.— RESISTOR ASSIGNMENTS.

Water Distribution System, Warwick, R. I.

DOMESTIC LOAD TABLE.			BUSES.		k	Assumed Flow ma.*	Res. Ohms.	RESISTOR.	
			From.	To.				Size Ohms.	No. R
Load at Bus.	Flow g.p.m.	Flow ma.*	25	26	34.4	191.8	8.5	10	1
			26	17c	90.6	140.0	17.0	100	50
			17c	3	480.0	137.5	89.0	100	51
1	120	6.00	3	1	680.0	135.8	123.0	4 000	61
3	35	1.75	1	4	4060.0	37.5	248.0	4 000	62
7	60	3.00	4	11	1445.0	65.0	150.0	4 100	32 and 64
10	45	2.25	11	2	920.0	50.0	75.0	110	33 and 6
11	300	15.00	1	10	3850.0	92.3	505.0	4 000	65
12	230	11.50	10	2	1706.0	90.0	220.0	4 000	66
13	105	5.25	4	5	1748.0	12.5	42.0	100	28
15	215	10.75	5	12	1314.0	11.5	29.8	100	29
16	50	2.50	5	14	1965.0	1.0	5.5	110	2 and 26
17b	30	1.50	14	13	806.0	5.3	9.4	110	5 and 30
19	55	2.75	12	13	27200.0	0.0	...	4 000	67
20	25	1.25	26	24	1794.0	50.0	140.0	4 000	69
21	55	2.75	24	23	2185.0	42.8	152.0	200	27 and 31
22	195	9.75	23	8	656.0	38.5	40.5	100	34
23	85	4.25	8	18	1488.0	24.8	64.0	100	35
24	145	7.25	8	21	13150.0	2.8	93.0	200	36 and 47
26	35	1.75	8	22	8520.0	11.0	182.0	4 000	70
17c	50	2.50	21	9	26300.0	0.0	...	4 000	71
			22	9	2660.0	1.3	10.6	110	37 and 10
Total	1 835	91.75	18	19	2345.0	2.8	16.6	110	38 and 9
			20	19	6110.0	0.0	...	100	39
			9	20	5030.0	1.3	20.0	100	40
			18	17b	875.0	22.0	33.8	100	41
			17b	7	961.0	20.5	35.0	100	42
			7	6	862.0	12.5	21.0	100	43
			7	15	19700.0	5.0	222.0	4 000	72
			6	15	3780.0	5.8	46.0	100	44
			14	15	7880.0	0.0	...	100	45
			14	16	64.8	−4.3	0.63	10	3
			16	6	378.0	−6.8	5.8	20	4 and 7

*For convenience values of the current have been shown in milliamperes instead of amperes.

second and third balancing operations. After the third balancing the currents were read, and as they were found to have changed only slightly the operation was complete. Voltage drops were then read and conversions made to pressure drops and hydraulic discharges. The resulting elevation of the hydraulic gradient at the end of each element is shown in the last column of the table. Figure 6 shows the pressure gradients by means of contours or equal-pressure lines for the fire load at Point 2.

Table 7 shows the balancing operations for a 1 500-g.p.m. fire load at point 6. Figure 7 shows the pressure contours for this fire load.

Precision. In considering the accuracy of the solution of an hydraulic problem obtained by means of the network analyzer, there are two aspects which are best treated separately. The first relates to the accuracy of the hydraulic data upon which the analyzer solution is based, the second to the precision of the analyzer results assuming that the hydraulic data are exact.

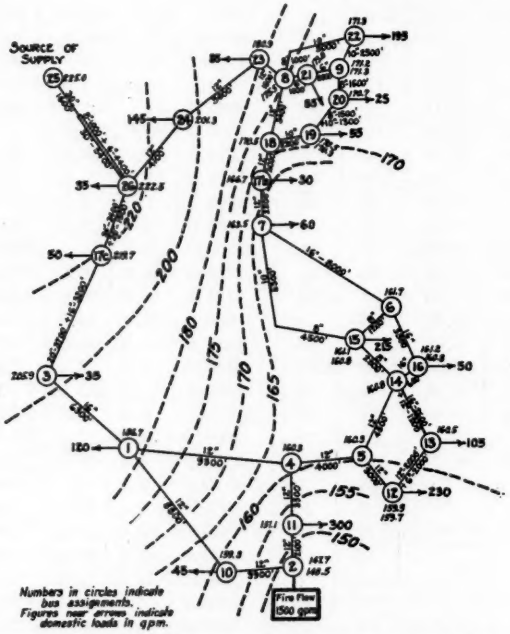

FIG. 6.— WATER DISTRIBUTION SYSTEM, WARWICK, R. I.
Pressure Gradients for Fire at Point 2.

In considering the first aspect, it is necessary to examine the nature of the hydraulic data, which include head-flow relations for the pipe elements, and specified flows or losses in head. Since definite values are arbitrarily assigned to the latter, they may be taken as exact data. The head-flow relations on the other hand introduce uncertainties. Under the most favorable conditions for accuracy of calculation, in which the flow in all pipe elements is such that the same value of x in equation (1) is properly applicable, the coefficient c is subject to uncertainty. Thus for a pipe element taken at random from an existing network, the value of n in equation (2) may be estimated at say 0.013 when its actual value is 0.015; and n is thus

subject to an uncertainty of as much as 15 per cent. The value of c, depending on the square of n, is therefore subject to an uncertainty of as much as 30 per cent.

If, as is usual, the flows in the various elements are such that x is not a constant from pipe to pipe, but is assumed constant, an additional error is introduced which cannot be readily evaluated. Although these two para-

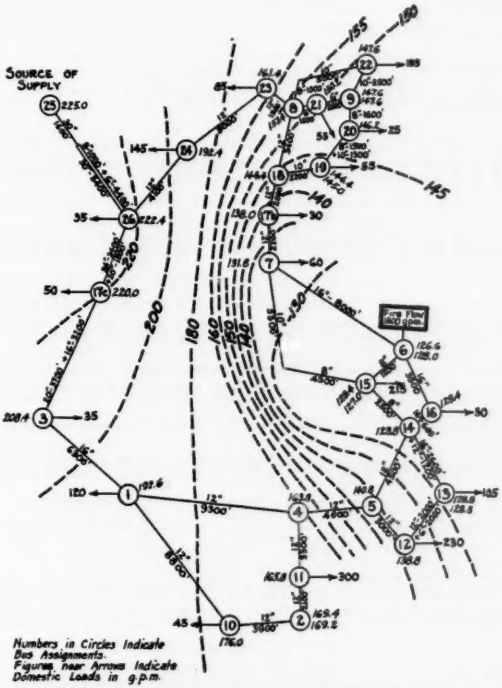

FIG. 7.— WATER DISTRIBUTION SYSTEM, WARWICK, R. I.
Pressure Gradients for Fire at Point 6.

meters characterizing individual elements are subject to wide variations, it is usual for these variations to offset each other to a considerable extent when their effects are averaged over an entire network, so that the observed loss in head between two points separated by numerous elements may frequently agree to within ten per cent. of calculated values. The lost head and flow observed in any given element may, however, vary widely from the calculated value.

The second aspect, that relating to the precision of the analyzer results, is not so easily analyzed. There are several sources of error which react on

TABLE 6. — PRESSURE DROPS DUE TO DOMESTIC LOADS AND 1500-G.P.M. FIRE FLOW AT POINT 2.
Elevation of Hydraulic Gradient at Point 25 = 225.0 Ft.

ELEMENT.				BALANCE 1			BALANCE 2			BALANCE 3		Meas. Flow, ma.	Voltage Drop, volts.	Flow, g.p.m.	Pressure Drop, ft.	Elev. Hyd. Grad., ft.
Buses		Res. No.														
From.	To.	R	k	Bal. Res., ohms.	Bal. Flow, ma.	Voltage Drop, volts.	Bal. Res., ohms.	Bal. Flow, ma.	Voltage Drop, volts.	Bal. Res., ohms.	Bal. Flow, ma.					
25	26	1	34.4	7.4	163.0	1.25	7.5	166.0	1.3	7.5	166.6	168.5	1.25	3 370	2.5	222.5
26	17c	50	90.6	13.0	181.3	1.35	13.0	182.0	1.5	13.0	104.5	104.0	1.4	2 080	2.8	219.7
17c	3	51	480.0	69.0	101.2	6.8	67	100	6.8	69	101.3	101.6	6.9	2 032	13.8	205.9
3	1	61	680.0	96	99.3	9.7	96	98.2	9.8	96	99.3	99.6	9.6	1 992	19.2	186.7
1	4	62	4060.0	312	49.1	12.9	288	44.3	13.3	292	45.8	46.3	13.2	926	26.4	160.3
4	11	32 and 64	1445.0	118	51.8	5.8	102	45.7	5.0	104	44.4	44.5	4.6	890	9.2	151.1
11	2	33 and 6	920.0	54	35.5	1.4	45	29.2	1.4	45	29.2	29.2	1.3	584	2.6	148.5
1	10	65	3850.0	272	44.3	13.3	288	47.7	14	292	47.9	48.0	13.7	960	27.4	159.3
10	2	66	1706.0	124	45.5	5.8	124	45.5	5.7	124	45.6	45.8	5.8	916	11.6	147.7
4	5	28	1748.0	7.0	−1.5	0.0	5.0	0.9	0.0	6.0	1.4	1.8	0.0	36	.0	160.3
5	12	29	1314.0	25	9.2	.25	24	9.0	.25	25	9.3	9.4	.2	188	.4	159.9
5	14	26 and 2	1965.0	40	−10	−.4	34	−8.4	−.35	32.5	−7.9	−7.8	−.25	−156	−.5	160.8
14	13	30 and 5	806.0	12.5	7.4	.1	12.5	7.6	.15	13	7.8	7.8	.15	156	.3	160.5
12	13	67	27200.0	180	−2.8	−.5	164	−2.5	−.4	164	−2.4	−2.4	−.4	−48	−.8	159.7
26	24	69	1794.0	164	60.2	10	168	62.2	10.4	168	63.3	63.2	10.6	1 264	21.2	201.3
24	23	31 and 27	2185.0	180	53	10	182	54.7	10	186	55.7	55.8	10.2	1 116	20.4	180.9
23	8	34	656.0	60	57.8	3	52	51.2	2.9	53	51.5	51.5	2.7	1 030	5.4	175.5
8	18	35	1488.0	82	33.7	2.5	81	33.2	2.8	82	33.5	33.5	2.5	670	5.0	170.5
8	21	36, 47, 48	13150.0	220	8.0	1.75	200	7.3	1.4	192	6.9	6.9	1.25	138	2.5	173.0
8	22	70	8520.0	192	11.7	2.2	192	11.5	2.2	192	11.5	11.6	2.1	232	4.2	171.3
21	9	71	26300.0	168	2.7	.4	228	3.9	.9	232	4.0	4.0	.9	80	1.8	171.2
22	9	37 and 10	2660.0	12.3	1.8	0.0	14	2.1	0.0	11	1.6	1.5	0.0	30	.0	171.3
18	19	38 and 9	2345.0	9.4	−1.5	0.0	10.3	−1.7	0.0	7.8	−1.3	−1.1	0.0	−22	.0	170.5
20	19	39	6110.0	45	3.1	.1	58	4.2	.2	58	4.1	4.0	.2	80	.4	170.3
9	20	40	5030.0	47	4.1	.2	59	5.4	.3	60	5.5	5.5	.3	110	.6	170.7
18	17b	41	875.0	47	32.5	1.6	50	34.1	1.8	50	34.5	34.8	1.9	696	3.8	166.7
17b	7	42	961.0	50	31	1.5	52	32.6	1.8	52	32.7	32.9	1.6	658	3.2	163.5
7	6	43	862.0	35	23.2	.8	36	24.1	.9	37	24.4	24.5	.9	490	1.8	161.7
7	15	72	19700.0	220	5.0	1.0	228	5.3	1.2	232	5.4	5.2	1.2	104	2.4	161.1
6	15	44	3780.0	40	4.9	.25	46	5.7	.3	46	5.7	5.8	.3	106	.6	161.1
14	15	45	7880.0	20	−.9	0.0	12	0.5	0.0	0.0	0.2	0.0	0.0	0	.0	160.8
14	16	3	64.8	2.0	−16.3	0.0	2.0	−16.3	−.1	1.9	−15.4	−15.4	0.0	−308	.0	160.8
16	6	4 and 7	378.0	12	−17.5	−.2	12.7	−18.6	−.25	12.9	−18.0	−18.9	−.25	−378	−.5	161.2

TABLE 7. — PRESSURE DROPS DUE TO DOMESTIC LOADS AND 1500-G.P.M. FIRE FLOW AT POINT 3.

TABLE 7. — PRESSURE DROPS DUE TO DOMESTIC LOADS AND 1500-G.P.M. FIRE FLOW AT POINT 6.
Elevation of Hydraulic Gradient at Point 25 = 225.0 Ft.

ELEMENT.				BALANCE 1.		BALANCE 2.		BALANCE 3.		Meas. Flow, ma.	Voltage Drop, volts.	Flow, g.p.m.	Pressure Drop, ft.	Elev. Hyd. Grad., ft.
Buses.		Res. No.		Bal.	Bal.	Bal.	Bal.	Bal.	Bal.					
From.	To.	R	k	Res., ohms.	Flow, ma.	Res., ohms.	Flow, ma.	Res., ohms.	Flow, ma.					
25	26	1	34.4	7.5	172	7.5	165	7.4	166.5	....	1.3	3 325	2.6	222.4
26	17c	50	90.6	12	96	12	89	12	91	91.5	1.2	1 830	2.4	220.0
17c	3	51	480.0	65	95	60	86.5	61	88	88.8	5.8	1 776	11.6	208.4
3	1	61	680.0	90	94.5	84	87	84	86	86.8	7.9	1 736	15.8	192.6
1	4	62	4060.0	348	54	308	48	300	46.1	45.5	14.4	910	28.8	163.8
4	11	32	1445.0	46	−17	47	−17.5	48	−17.7	−18.0	−1.0	−360	−2.0	165.8
11	2	33 and 12	920.0	47	−31.7	50	−33	50	−33	−33.2	−1.8	−664	−3.6	169.4
1	10	65	3850.0	248	39	232	36.5	224	35.7	35.7	8.3	714	16.6	176.0
10	2	66	1706.0	108	38.5	96	34.4	96	33.3	33.2	3.4	664	6.8	169.2
4	5	28 and 64	1748.0	140	55.3	168	63.6	168	63.7	63.4	11.5	1 268	23.0	140.8
5	12	29	1314.0	40	16	48	20.3	50	20.8	21.0	1.0	420	2.0	138.8
5	14	2, 26, 27	1965.0	105	31.7	120	40.2	134	42.4	42.4	6.0	848	12.0	128.8
14	13	30 and 5	806.0	10.2	−5.8	9.5	−5.5	7.5	−4.2	−3.5	0.0	−70	.0	128.8
12	13	67	27200.0	396	7.0	480	8.8	500	9.3	9.2	5.0	184	10.0	128.8
26	24	69	1794.0	196	74.5	196	74	196	73.8	73.0	15.0	1 460	30.0	192.4
24	23	48, 49, 46	2185.0	215	65.5	220	66.2	220	66.6	66.5	15.5	1 330	31.0	161.4
23	8	34	656.0	60	61	62	61.7	61	62.2	62.0	4.0	1 240	8.0	153.4
8	18	35	1488.0	96	40	97	41.3	98	42	41.7	4.5	834	9.0	144.4
8	21	36, 11, 47	13150.0	205	7.6	205	7.5	205	7.6	7.4	1.6	148	3.2	150.2
8	22	70	8520.0	212	12.8	216	13	216	13.1	13.0	2.9	260	5.8	147.6
21	9	71	26300.0	264	4.5	276	4.7	280	4.8	4.5	1.3	90	2.6	147.6
22	9	37 and 10	2660.0	20	3.2	20	3.3	20	3.3	3.0	0.0	60	.0	147.6
18	19	38 and 9	2345.0	16	−2.8	20	−3.8	20	−3.8	−3.6	0.6	72	.0	144.4
20	19	39	6110.0	80	6.1	85	6.5	85	6.7	6.3	.6	126	1.2	145.0
9	20	40	5030.0	80	7.7	82	7.8	83	8.0	7.8	.7	156	1.4	146.2
18	17b	41	875.0	60	42.8	63	45	63	45.6	45.4	3.2	908	6.4	138.0
17b	7	42	961.0	63	41	65	43.2	68	44	43.8	3.1	876	6.2	131.8
7	6	43	862.0	47	32.3	48	33.8	50	35	34.3	1.9	686	3.8	128.0
7	15	72	19700.0	248	5.8	264	6.3	252	5.9	6.0	1.7	120	3.4	128.4
6	15	44	3780.0	26	−2.8	0.0	0.0	43	−5.3	−3.9	−.2	−78	−.4	128.4
14	15	45, 16, 17	7880.0	78	4.6	64	3.5	112	6.8	7.2	.9	144	1.8	127.0
14	16	3	64.8	3.5	31.5	4.4	41.5	4.2	39.4	38.4	.2	768	.4	128.4
16	6	31	378.0	20	32	20	31	23	35.7	35.4	.9	708	1.8	126.6

one another in a complicated way. These include: the error in setting resistors due to finite steps; the calibration error of the resistors; errors of balancing; the errors due to the insertion of instruments; and calibration errors in instruments. The first three sources of error operate somewhat together, and their overall effect is difficult to estimate. It is probably most pronounced in the determination of the flow in a large short cross pipe, and relatively insignificant in any pipe in which the loss of head is an appreciable fraction of the total loss in head. The last two errors can, without difficulty, be kept within one or two per cent. of the quantities involved in individual elements.

In general it can be said that the overall analyzer error will not cause the value of c, as determined for a given pipe element from the electrical measurements, to differ from the given value by more than two per cent. in the average case or by more than five per cent. in an extreme case. The conclusion is then that the precision of the electrical method is such that the uncertainty of the hydraulic data is by a large margin the controlling source of inaccuracy in this method of the solution of hydraulic network problems.

Summary. The important points developed in this paper can be summarized as follows:

1. Due to the complexity of the hydraulic network problem, analytical methods of solution, though existent, are ordinarily impracticable in application.

2. Because of the similarity between the fundamental equations for hydraulic and electrical networks, hydraulic problems can be set up and solved on an electrical network.

3. A flexible type of electrical network called the network analyzer is described which is well adapted to the solution of hydraulic networks containing as many as sixty to eighty pipe elements.

4. The method and technique of making such solutions is described in detail and is illustrated by a simple example.

5. The method is applied to the solution of a representative hydraulic network which contains 33 elements and 19 loads and includes several loops.

6. It is shown that the method is more precise than the hydraulic flow formulas which furnish the data for the problem.

DISCUSSION.

H. E. BABBITT*. My discussion will do no more, possibly, than to raise a question and to voice a commendation. In order to leave the proper impression of my thoughts on the authors' achievement, it might be well to raise the question first.

In the resumé of the various known methods for the determination of pressure losses in distribution systems the authors have very lightly stressed the importance of the so-called "cut-and-try" method in which the original assumption must be a division of flow between the pipes involved and the final conclusion an equal loss of head by all possible routes of flow from one point to another. This is merely a statement, in different words, than those of the authors', of their second law: "the algebraic sum of the head losses around any closed circuit is zero."

The cut-and-try method has the advantage over the contour and the circle methods, to some extent, that flow can be taken from the pipes at any point by cut-and-try, but generally not by other methods. The electrical analogy possesses the advantage of the cut-and-try method, in this respect.

The equivalent-pipe method is applicable only to the most simple problems and piping systems because of the great multiplication of equations arising under even slight complications of the methods in which the pipes may be connected. It is sometimes impossible in the equivalent-pipe method, to express the losses properly because of the manner in which the pipes are connected. It is then customary to avoid this mathematical difficulty by ruthlessly violating the truth and throwing away all regard for accuracy in the result by assuming the pipes to be connected in some manner other than as they are. Such a modification produces an abomination, possibly nearer the truth and possibly further from the truth, than an unmitigated, unblushing guess.

The cut-and-try method, the unmodified equivalent-pipe method, and the authors' method have the advantage of inherent accuracy and precision limited only by the original assumptions of friction constants and the precision of the computations. The circle method, the contour method, and the modified equivalent-pipe method produce results which are incorrect and are not precise but which may, if good fortune has been combined with good judgment, come sufficiently near the truth to be of some practical value as a guide to the engineer's judgment.

In a critical comparison of the practical advantages of the cut-and-try method and the authors' method, since both methods will admittedly give equally good results, the question arises which method will give such results with the least time and effort. If the system is very simple, unquestionably the cut-and-try method will produce the result more quickly. If the system is extremely complicated, even more so than the authors' example for Westerly, R. I., it is possible — but I admit it

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grudgingly — that the method of electrical analogy in the hands of an expert might produce the result in a shorter time. That would remain to be proved by demonstration, and the human element of the skill of the computer and of the electrical experimenter would enter into the race.

A practical objection to the authors' method is the need for the possession of the electrical equipment, the ability to set it up, the knowledge required to use it, and the time consumed in the computations. The analysis of a complicated distribution system does not arise frequently in engineering experience. In the event that it does, since the problem might be solved by a computer in a day or a week, the cost of this time would possibly be less than the cost of maintenance of the electrical equipment in addition to the time required for its preparation, use, and the solution of the problem in hand.

It is to be noted in reviewing this paper that insufficient information has been presented for one to set up the electrical equipment; at least by one so ignorant in electrical equipment as the writer. I feel incapable, after having read the paper, of solving any problem by the method. This admission is made of my own inability and it does not detract at all from the advantages of the method to one acquainted with both the hydraulics of compound pipes and the use of electrical analyzers.

It is to be noted that so far in this discussion the accuracy of the authors' method has been admitted. To approach a decision as to the accuracy of the method by following the authors' proofs as the analysis is developed mathematically, step by step, is laborious and the suspicious pursuer may be misled along the wrong path by the elusive, mathematical blandishments. A conclusion can be reached far more easily and conclusively by checking the authors' results against their "second law." The results agree with the law; the results are correct; hence the method must be correct. What can be more satisfactory than a method whose results are correct?

I said, at the start of my discussion, that I would raise a question and express a commendation. The question has been raised and stated; now for the commendation. The flow of water through a pipe is not the same as the flow of an electric current over a wire. Water has mass; it suffers from internal friction; there are a number of losses of head (or potential) at bends, enlargements, and through appurtenances. The rubbing of the particles of water against the sides of the pipe cannot produce the same effect as the friction of a wave of electricity in passing along an electrical conductor. An electrical current has no mass, apparently has no internal friction, and it does not experience the so-called minor losses due to irregularities in the conductor. It cannot, therefore, suffer from the same symptoms as the flow of water. The danger of drawing too close an analogy between electrical and hydraulic flow, except possibly as an aid in class-room explanations, has long been held as a warning to instructors in hydraulics.

How then could the authors hope to find a solution of so complicated a hydraulic problem by drawing a precise mathematical analogy? The answer seems obvious; the case is hopeless but, like the trips of many successful predecessors in science who have struck out along apparently hopeless routes, the authors have returned from this apparently hopeless side trip with a new method which is both accurate and helpful.

To contribute a method for the solution of the complicated problems in connection with the determination of the flows and pressure losses in a distribution system is an achievement of value. To contribute a method which, under certain circumstances, will produce a result when all other methods fail is a triumph. Great credit is due the authors for their triumphal achievement.

EXPANSION OF THE FREEMAN METHOD FOR THE SOLUTION OF PIPE FLOW PROBLEMS.

BY W. E. HOWLAND.*

[*Received August 2, 1934.*]

The writer has been asked to present some of his own modifications of the John R. Freeman method for pipe-flow computations which have proved useful in practical computations. These methods were referred to at the Cornell meeting of the Society for the Promotion of Engineering Education in a discussion of a paper on an electrical analogy for pipe-flow computations by Professor Camp.†

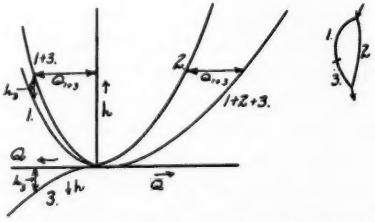

FIG. 1.— CONVENTIONAL SOLUTION OF PIPE FLOW PROBLEM BY FREEMAN'S GRAPHICAL METHOD.

The basic Freeman method is indicated in Fig. 1. The curves for the three pipes indicated are plotted in the three quadrants as shown. The curve of head loss for the combination of pipe (1) and pipe (3), which are in series, is obtained merely by adding, graphically, corresponding head losses at particular flows giving curve (1 + 3). The curve of head loss against flow for the entire system is then obtained by adding graphically the flows from this curve to the parallel flows of pipe (2) for particular head losses thus obtaining curve (1 + 2 + 3).

If, however, there is a take-off of a fixed amount at the junction of pipe (1) and (3), then the head loss of pipe (1) at a particular flow will have to be added to the head loss of pipe (3) for a flow less than the flow in pipe (1) by the amount of the take-off at their junction. This corresponds graphically to moving the curve for pipe (3) to the left by the amount of the intermediate take-off before the ordinates are added to obtain curve (1 + 3) shown in Fig. 2. The remaining part of the method is the same as before. The final curve (1 + 2 + 3) shows total head loss for the loop plotted

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†See this Journal.

against total inflow to the loop. This curve could, of course, be combined with the curves for other pipes in parallel or series by similar methods.

A further expansion of the Freeman method will serve the case of the cross-over. The cross-over is a complication of a loop but differs from a simple loop in that one or more pipes connect an intermediate point on one side of the loop with another intermediate point on the other side of the loop. A simple cross-over is shown in Fig. 3. This problem may be solved by

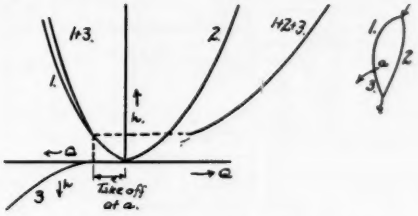

FIG. 2.— EXPANSION OF FREEMAN METHOD TO INCLUDE A TAKE-OFF.

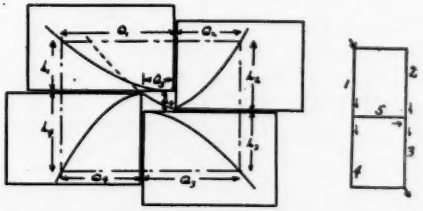

FIG. 3.— EXPANSION OF FREEMAN METHOD TO INCLUDE A CROSS-OVER.

plotting on cardboards or sheets the curves of head loss against flow for the four pipes (1), (2), (3), and (4) as shown. All boards are made to fit closely together with a small rectangular space appearing between them through which shows a portion of the head-loss flow-curve for pipe (5). This curve is plotted on a thin sheet attached to the side of the cardboard for pipe (2). Its vertex is coincident with that of pipe (2), and the boards should be so arranged that it passes through the upper left corner of the rectangular space which defines the intersection of the horizontal axis of curve (1) with the vertical axis of curve (4). It appears now that points on each of the curves (1), (2), (3), and (4) which form the corners of a rectangle represent a total flow, and a corresponding total head loss for the cross-over system for which one could readily obtain the equivalent length. (In subsequent computations this system could be treated as a single pipe of this length.) The total flow is $Q_1 + Q_2 = Q_4 + Q_5 + Q_2 = Q_4 + Q_3$, and the corre-

sponding total head loss is $h_1 + h_4 = h_1 + h_5 + h_3 = h_2 + h_3$. To apply this procedure to any system of pipes a family of head-loss flow curves can be constructed and duplicated from which one may readily select the appropriate curves to be used for any particular problem.

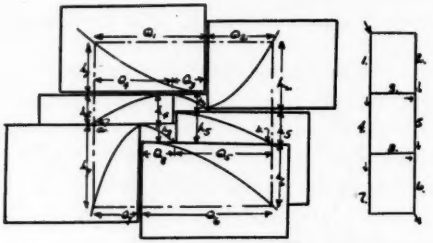

FIG. 4.— EXPANSION OF FREEMAN METHOD TO INCLUDE MORE THAN ONE CROSS-OVER.

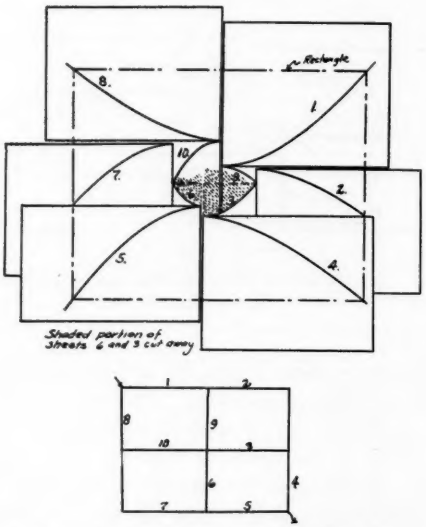

FIG. 5.— GENERAL SOLUTION OF A GRID SYSTEM BY THE EXPANDED FREEMAN METHOD.

A constant intermediate take-off at the junction of pipe (4) with (5) or of (5) with (3) can readily be accommodated merely by moving (4) to the left by this amount in the first case, or (3) to the right in the second. A cardboard of appropriate width placed between cardboard (4) and (3) is convenient in this case.

Similar methods can be used for two or more intermediate pipes as shown in Fig. 4. Curves (3) and (8) are located on sheets attached to the side of cardboards (4) and (7) respectively. Curves (1), (2), (4), (3) and (5) may be fixed and then cardboards (7) and (8) moved to find the rectangle. Not only must the corners of the rectangle lying on the curves (1), (2), (6) and (7) be found, but at the same time also additional necessary conditions must be satisfied. The points marked (a) and (b) lying on curves (4) and (5) and also on the horizontal axes of the lower curves must lie vertically below the upper left and right corners respectively and the curves for (3) and (8) must fit correctly at the rectangular corners or openings so that $Q_1 + Q_2 = Q_4 + Q_3 + Q_2 = Q_7 + Q_8 + Q_5 = Q_7 + Q_6$ and also $h_1 + h_4 + h_7 = h_1 + h_4 + h_8 + h_6 = h_1 + h_3 + h_5 + h_6 = h_2 + h_5 + h_6$.

The following statement of these conditions fits closely these equations: The head loss by every path between any two points in the system must be the same, and the sum of the flows in the various paths to every point must equal the total of the flows away from that point.

In a similar manner one may attack by these methods a grid system as shown in Fig. 5; but here still more cardboards — (in this case, four) — must be moved or adjusted before one can locate the corners of the desired rectangle. Curve (10) is located on a sheet attached to the bottom of cardboard (8); curve (9) is attached to the bottom of (1); curve (6) to the top of (5); and curve (3) to the top of (4). The sheets on which curves (6) and (3) are located are cut out along the respective curves or the sheets are made transparent, allowing curves (10) and (9) to show through. The method of satisfying the necessary conditions in this case should be evident from the figure.

These methods have been found useful for a variety of pipe systems, particularly for those which consist largely of separate loops not interconnected at many places. I believe they would serve for the solution of the problem presented in Professor Camp's paper, although I have not had opportunity to examine that problem closely. For more complicated grid systems still more powerful methods, such as those presented by Professor Camp, would seem to be useful.

PUBLIC WORKS FOR ECONOMIC STABILIZATION.

BY WILLARD T. CHEVALIER.*

[*Read September 18, 1934.*]

When Edmond Rostand wrote L'Aiglon, that pathetic drama of Napoleon's unfortunate son, a controversy still raged in France concerning the legitimacy of the succession. There still was dispute as to who was the rightful ruler of France. And so he wrote as a foreword to his play that verse which, translated freely into English, reads as follows:

> "Great God, this is not a cause which I am attacking, or which I am defending; this is nothing but the story of an unfortunate little child."

I find myself somewhat in the position of Rostand, because I have been so long associated with this subject of public works as one of the recovery measures that whenever I am introduced to discuss this subject I am regarded at once as an advocate of a cause. And so I say, this is not a cause that I am going to attack or defend; I am simply going to give you the benefit of some random observations and reflections that have come to me during the last year or two as we have contemplated the effort to put a public works program to work in behalf of economic recovery.

One of the first difficulties under which we labor in considering the question is that of defining what we mean by public works and the public works program. I find the most pathetic misunderstanding on this subject by citizens generally and by industrialists and business men who, you would think, should know better. For example, during the last year I have heard frequent references, on the score of the public works program, to the RFC, the CCC, the CWA, and the TVA, as well as the PWA. In the minds of a great many of our citizens all of these enterprises are lumped in the general term of public works, and whatever may be their reaction to any one of those particular enterprises is their reaction to public works of any sort.

Of course that is not right. Each of those five agencies to which I have referred has a specific mission. They are quite different in objective and in intent. There is all the difference in the world between relief, recovery, and reform. Today we are living under an administration that is attempting to carry on this threefold task of achieving relief, recovery, and some measure of reform.

Each of these agencies is directed especially to one of those ends rather than to the others. For example, the RFC was a recovery measure. It was designed to supplement the ordinary banking system. It enabled the Federal Government to assume a banking function. Observe, in passing, that this was the first step in the New Deal, and that it was taken before the advent of the present administration. The first departure from the normal

*Vice President, McGraw-Hill Publishing Company, New York, N. Y.

process of deflation, from the normal process of the business cycle, was the effort of the Federal Government to put the national credit behind private business and private banking. The RFC, then, was a recovery measure designed to provide credit for American business and American industry.

The CCC, on the other hand, was a relief measure, pure and simple. It was designed to assemble and discipline a large proportion of the idle on a mere subsistence basis. It was intended to forestall potential social upheaval, to prevent the upheaval that might come with hundreds of thousands of idle men hanging about our communities and to put them where they could be maintained on a subsistence basis and brought under some sort of organization. It is true that it was hoped that their work would be useful, but CCC was primarily a relief measure.

The same applies to the CWA, which again was a relief measure. It was designed to put on the public pay roll in the form of useful employment, rather than of a dole, those people who had to stay at home in their communities and could be put to work in some capacity for the community, but there was very little consideration as to the economic value of what they might produce in the process. The main object was one of relief, of temporary employment in the public service, rather than a dole.

The TVA is a reform measure. The TVA is a great social and economic experiment. It is an attempt to determine the limits to which we may go in national community development. It is a great experiment in regional planning and an effort to ascertain and apply certain social and economic ideas that have been much discussed and must be a part of any program of national planning. Such construction work, such structures as must be provided in connection with it are quite incidental to the purposes of the project. It is a reform measure primarily, which happens to have certain relief and recovery aspects.

The Public Works Administration was distinctly a recovery measure, because it was designed to revive and stimulate public investment, as being perhaps the only source of capital investment to which the harassed capital goods industries might turn for markets during the paralysis of private investment. So it was distinctly a recovery measure.

I have gone to this trouble to define these terms simply to indicate that in my judgment a great deal of the difficulty in understanding a sound public works program is because of a confusion of these agencies and their various missions.

The second reflection that comes to me in this connection is that public works are a part of public business, not a part of the function of the government. It is the business of providing the fixed structures that are required for public service facilities.

I should like to draw a very sharp distinction, if you please, between the civil functions of government and the economic functions of the community, which happen to be carried on by the same agencies as administer the civil functions. The enactment of laws and the exercise of the police

power of the state are governmental functions; they are civil functions; they are the processes of government. But when government builds and operates a water works or sewerage system, builds a highway or a reclamation project, it is not engaging in one of the civil functions of government; it is engaging in an economic enterprise.

That calls for a rather sharp distinction when we come to discuss this vexing question of the cost of government. The cost of government *per se* — that is, the exercise of the civil functions — is very properly kept, or should be kept, at a minimum at all times, because it represents an operating and administrative expense. It is community overhead. And I am of the opinion today, that one of our great shortcomings as a community has been our failure to take advantage of the great progress that we have made in our public works facilities to reduce the cost of government *per se*.

Let me just cite one example to illustrate what I mean. Let us contemplate the multiplicity of governmental units that we have in this country today — towns, townships, counties, and whatnot — each one supporting its horde of office holders, each one with its inevitable expense, each one with its duplication. Then recall that many of those agencies of government were set up 100 years or more ago when our only means of transportation was the oxcart and the dirt road, when it was necessary to get the county seat and the court house within the reach of every farmer by an animal-drawn vehicle so that they could conduct the business of the community. But today, with automotive transportation, as we drive along one of our modern roads, these county seats are strung like beads on a necklace, within 15 or 20 miles of each other. We have no more need for them than a cat has need for two tails, but we are preserving a structure of government that is wasteful and extravagant in the extreme. That is because we have not learned how to administer government by making use of the great improvements that we have made in our transportation facilities. This is but one example of many where the cost of government itself, the civil function, is much greater than it need be. We have not used our investment to help reduce our operating expense.

When we come back to the expenditures that are made for our public facilities, we have a different picture. Those expenditures represent an investment of capital in some form just as truly as does the erection of a factory or a power plant, or any other form of enterprise. There we must set up a community balance sheet, wherein we set down on one side the investment of capital that we make in those facilities, and on the other their value to the community measured in the comfort, convenience and productivity of the people who live in the community and have the use of the facilities. This calls for an entirely different economic approach. That is why I prefer to think of public works as an activity of the community rather than as a governmental activity.

This makes it important also to distinguish between the national government and state and local governments, because the national govern-

ment has certain economic functions that absolutely prevent its problems being considered on the same basis as those of the local community. The local community must balance its books on a money economy, just as the individual does, but the nation must balance its books on a wealth economy regardless of money values. It is folly to talk about balancing the federal budget on the same basis as that of a local community or an individual.

Another point to be recognized is brought very much to the foreground by recent developments. When government enacts laws for the control of business, it is limited only by the provisions of the constitution under which it acts. It has the right under the constitution to set up certain regulation or control of private business activities that may be in the public welfare. But when the government as an economic unit enters the arena of business it must be bound by those laws just the same as any private citizen is bound.

When the government, for example, establishes, under its constitutional powers, codes to control the minimum prices for commodities, it has a perfect right to do so. But, if it then, as an economic agency, enters the arena of business to buy, sell, and trade in the services and products of its citizens, it has absolutely no right to set up for itself provisions whereby it can buy on a lower basis than any one of its citizens can buy in that market. Nor has it any right to set up any provision for its own purchasing which violates any provision of the codes under which its citizens must operate. That is an absolute perversion of the proper function of government, and it can be excused only on the ground that there is a lack of understanding as to the distinction between government functioning as the civil power and government functioning as an economic agency; i.e., going into the market place to buy and sell the services and commodities of its citizens.

It is perfectly evident, I think, that excessive participation of government in the exchange of the services and commodities of its people can have but one end, and that is what we call socialism, which is simply the assumption by the community of the full responsibility for effectuating the exchange of the goods and services of its people. Today the problem is that of striking a balance between two opposing views. First, that government should do nothing more than to exercise its civil powers to keep the ring clear, so that untrammeled private, individual initiative and enterprise shall go just as far as they can and just as far as they choose in the conduct of commercial operations. That is the one extreme view. The government should do nothing more than keep the ring clear, it should not build and operate water works, it should not build and operate a sewerage system, it should not build and operate any of those facilities which serve the economic well being of our people as contrasted to their civil government. The other extreme is that the government shall provide the clearing house through which shall pass the exchange of all the goods and services produced by our people; in other words, the government shall become the business center of the nation. That, of course, means socialism.

Now, somewhere in between those two we must find our answer. We

must determine just what services and facilities can most effectively be provided by the government for the community, and what should be left to private enterprise to carry on most effectively in the interest of the whole community.

It is obvious that during the last fifty years we have seen an increasing assumption by communities of various services. There was a time when the actual policing of the streets, the keeping of law and order, was a private business. Today there are many thousands of private policemen in many of our cities. That is a private business. But we have decided that the performance of this function is so vital to the life of a community that the government should take over that business and run it.

The same applies to fire protection. There was a time when the rendering of fire protection was a private business, and when the subscribers to the service were the only ones whose premises were protected. Then the community decided that that practice entailed too great a risk and that everybody would have to have fire protection, so that the community provided it and taxed the people for that particular service, which, mark you, is an economic service.

So with the water supply, so with sewage disposal, and so with all the rest, until we get into the debatable zone of various services of one shape or another. Now we are debating the question every day: is this a proper function for the community to carry on as a business, or should this function be left to private initiative and enterprise as a business?

I am through looking upon all these questions as either black or white. I think we must simplify a great many of these questions. A great many of them are neither black nor white; they are gray, and it is up to us to determine what degree of grayness we require in any particular enterprise. But it is obvious that this increasing participation by the communities in economic activities brings the government and governmental powers into business and industrial life.

Students are now trying to find out, not only how government can thus participate in business, in the providing and operating of facilities, with the maximum economy and efficiency, but also how the economic effect of this can be exercised beneficently rather than harmfully upon general business. In other words, if government must get into business of one sort or another, how can it manage with respect to time, place, and nature of activity so that the effect of its participation will be for the general good of the economic cycle rather than an evil.

To make this statement more specific, if we build public works on a large scale at the height of an inflationary boom, we are using the government's entrance into an economic field to further complicate and vex an already difficult situation. On the other hand, if the government enters into that very activity on a large scale at a low period in the business cycle, it may be exercising a beneficent influence on general business by its entrance into the economic cycle. That is one of the many questions to

which students are seeking an answer today: How can government exercise its business functions to the best advantage of everyone concerned?

Right here I should like to deliver myself of an *obiter dictum*. I should like to comment on the matter of the relative effectiveness in the conduct of private and government business. There is a widespread assumption on the part of some of our people, assiduously fostered by various minorities, that the conduct of business by a community itself is necessarily extravagant and inefficient as compared with the operation of private business and private industry. If you will say that this may be true of this community as compared with that business, there can be no quarrel. But, on the other hand, if you make that statement of all community business as compared with all private business, I am not so sure. For example, it is said that we are extravagant in the administration of our public affairs because we have the taxing power and the use of other people's money. It is commonly said that it is one thing to spend an appropriation and another thing to earn a dividend. It is also said that the influence of politics governs rather than the public good. It is further said that, from the very nature of the employment, the public service must be inefficient in operation, and public enterprise must be inefficiently managed.

I am not going to attempt to prove the truth or falsity of such assertions. As I say, each individual case must be considered on its merits. But I am going to ask a few questions, which are pointed to those who accept such conclusions and assumptions so easily.

First, has the investment in public facilities been any more extravagant in the past than that of private business and industry? Have we, through investment in the capital facilities of our community, done any worse than private enterprise has done? I shall let you answer the question yourselves as to where the greatest extravagance in the investment of capital has prevailed.

Second, are the stockholders of a large corporation any more powerful or alert in protecting their interests in big business than are the taxpayers in protecting the community business? If you have any doubts on that subject, read the very interesting work by Berle and Means on "The Modern Corporation and Private Property" and get some idea as to just how much the stockholder has to say about the use of his money. As a matter of fact, most of those who manage our great business enterprises are playing with other people's money, just as much as the public officials are playing with other people's money. And the stockholders have just about as little to say about what is done with their money as do the taxpayers in any community.

Louis D. Brandeis, now a member of the Supreme Court of the United States, wrote a very interesting book some time ago on "Other People's Money," and I want to remind you that it was not the taxpayer's money that he was talking about at the time.

Next, I want to ask: Is politics absent from business and business

organizations? Is every business organization carried on as a family affair, where everyone is thinking only of the welfare of the business, where personal aspirations are laid aside and politics are unknown? Is not business very often a partner of party politics? How often are corrupt party politicians but the tools of private business and industry?

We finally come to the question of operating efficiency. Is the operating inefficiency of public enterprise more wasteful or destructive than the financial inefficiency or depredation of private enterprise? If we admit — which I do not — that the engineers, the technical men and the operators who manage our public business enterprises, are less efficient technically, is not the superior technical and managerial efficiency of those men in private enterprise outweighed by the financial inefficiency and depredation of private enterprise? Not very long ago we witnessed a vast waste of capital and property by those in control of private enterprise. Can't we set off financial inefficiency against technical inefficiency? I think public enterprise would stand up very well under such a comparison, taking both the technical and financial sides together. It was not the public securities that were used to rig investors and the public during the last decade. The story of 1922 to 1929 was not a story of excessive expansion of public facilities or of squandering by public agencies — not at all.

Furthermore, it is common for those in charge of private business and industry to say "The government should economize just as I have done, just as my business has done; the government should adopt the same principles of economy and thrift in operation which I have had to do." That is a very specious argument and will not stand analysis. When I ask the private business man how he economized how he cut down expenses, the answer is that he did it by firing some of his people; he cut his pay rolls. But, I ask, where did those people go? They did not disappear into thin air. Human beings can't be preserved and put on ice until they are wanted and then thawed out and put to work. It is not so simple as that. When the private individual or the private corporation economizes in its management it immediately throws the burden upon the public; it just takes men off its individual pay roll and places the burden of supporting them upon the taxpayer. But government cannot economize so easily as the individual can, it cannot apply the same principles to the administration of public bookkeeping that are applied to the private individual and corporate bookkeeping.

I say these things, not in any way to belittle the ability or the honesty or the efficiency of private business and private enterprise — not at all. I do it simply to answer those who so lightly assume that public expenditure and public investment are of necessity extravagant, wasteful, and inefficient. I do not believe it. Therefore, I am not impressed by those who think that because a community is investing the larger part of its savings and its capital in community facilities, that of necessity is going to breed waste and inefficiency. On the other hand, I do believe that private business and

industry are in general best adapted to create and distribute our wealth, to exchange our services, to stimulate progress in the arts and sciences, to raise our standards of living. I believe that just as far as we can we must maintain private enterprise, private initiative, the spur of individual gain and individual profit as the agencies which will stimulate us to try and do things better.

How much of our progress to date in science and in the arts, how much of our progress in engineering, how much of our progress in public works construction and operation is due to the private manufacturer of machinery, equipment, processes, and so on. He does it because of his own interest, in the hope that he will gain an advantage, in the hope that he can do something better than his competitor, in the hope that he will be able to widen his profit margin by virtue of more efficient production. It is that constant spur to greater efficiency in production and to producing a better product by which he can show greater efficiency in operation, that we progress to higher standards of efficiency; which means higher productivity and higher standards of living by everyone. Before we can have an abundance for all we must have an abundance, and we can't have maximum efficiency until someone takes the results of research and applies them to the agencies that are going to benefit by them in the productive industries. I believe today just as firmly as ever that this can be accomplished best by helping private business and private enterprise to carry on under a competitive system.

But may I emphasize a BUT. If that system is going to work, we shall have to make it safe for the creators and producers of that wealth. We shall have to provide that the fruits of their genius and their energy and their ability do not go to the predatory parasites of speculation. We must begin to put more emphasis on the creation of wealth and less on the acquisition of wealth. We must learn that the man who makes a speculative profit has added nothing to the wealth of the world, and that when he takes his speculative profit he has taken it away from someone who has created it; there is no other way that he can get it. This business of acquiring wealth by virtue of the ability to manipulate credit, to manipulate those symbols of wealth which represent credit, and otherwise to play the game of acquisition — that kind of manipulation in this country will have to go, or be materially curbed, if we are to insure to a creator, a producer of wealth, the enjoyment of the fruits of his own genius or labor. And so I say that, with all of my respect, with all of my faith in the system of private business and private enterprise for industry, it is going to survive only in proportion as it curbs predatory speculation in wealth by those who have made no contribution to its creation.

With respect to the present public works program I propose to take very little time. What I have tried to do up to now is simply to lay a foundation for a philosophy of public works which will be honest and straightforward, which will get away from the slogans and prejudices of those who have talked a great deal about it but understood little of what it means.

With respect to the present effort, I might say that the public works program was not struck out full armed from the brain of the Brain Trust; on the contrary, it grew like Topsy, and that was one of its troubles.

The present public works efforts started with a banking strike. In 1930 and 1931, when the fountains of private credit were dried up, the communities that had projects with which they wanted to go ahead were unable to get banking accommodations. Through a modification of the Reconstruction Finance Corporation it was made possible for the national credit to be made available for such communities. That was an effort to feed in credit from the top, and it worked to a certain degree. But nevertheless, it did not work as it should. Then came the new administration, simply extending and amplifying that principle at first, and then reënforcing it by providing an inducement in the form of a 30 per cent. grant for labor and materials, but again acting as banker for the remainder of the cost of the project. Today we see that project successful to the degree that some of the bonds that were taken by the Reconstruction Finance Corporation as banker for the PWA, are being sold through private investment sources at a premium. In other words, the private banking agencies are beginning to resume their function so far as community credits are concerned.

The difficulties of a public works program under present conditions are due to several circumstances, one of which has already been touched upon lightly. First, I should write down that the difficulty in getting it under way and making it quickly productive was because of the absence of a regional plan and a program of public works, making it necessary to improvise a program and projects on the spur of the moment.

Second, I should refer to that confusion of recovery with relief and use of methods that retarded private industry. To give you an example: When a public works project carries with it a provision that the contractor shall use hand labor instead of modern methods and machinery, that is a confusion of relief with recovery. As a recovery project it was intended that it should stimulate a demand for normal employment, and for the products of the capital goods industries. The moment that this was subordinated to the relief motive of making the largest possible amount of employment on the job for the largest number of individuals, relief was permitted to undermine recovery. That was a very serious difficulty in the inception of the public works program.

Furthermore, there was the competition of the relief measures, such as the Civil Works Administration, for projects. Projects that should very well have been carried on under Public Works Administration auspices were, by design, turned over into Civil Works Administration projects, so that the community would not have to make any contribution of its own but could get all the money from the Federal government under the guise again of relief rather than recovery.

Furthermore, there was the establishment of arbitrary restrictions that cannot be carried over into private investment. I refer to the labor restric-

tions which were written into the public works projects. These had a deterrent effect upon the progress of the enterprise.

Finally, I should write down: too great expectations, too great obstruction. On the one hand, there was the feeling on the part of some people that a public works program such as this would immediately stimulate the capital goods industries to tremendous activity; they were disappointed. Then there were those who were so dead set in their ideas of national finance and budget-balancing on some of the matters we have been discussing that they threw obstructions of every conceivable kind into the progress of the enterprise. All of this made its contribution toward holding back genuine progress.

Contrary to the views of some students of the question, I do not believe that those difficulties are insuperable. I do not believe that we are entitled to level such an indictment at the intelligence of the people as to say that difficulties such as these are insuperable. I believe that it is perfectly possible to establish a sound and enduring public works program in this country, which will have a stabilizing effect upon the economic cycle in operation if we will base it upon certain premises.

First, full knowledge of the national resources that affect public services and facilities, with a possible extension of government control into the field of national resources and natural resources beyond what we had up until the present time. That involves, of course, the work of the National Resources Board.

Second, long term regional planning — not local, not national, but regional. I choose that word deliberately. A region, as I see it, would perhaps include a drainage area or other natural division; perhaps a trading or commercial community; perhaps a transportation unity or network. The region must be the basis for our regional planning.

Next, I believe that regions for regional planning should be organized to cut political lines rather than follow political lines, and thereby set up regions which in their administration will make political influence more difficult.

Next, local projects must be able to fit naturally into the regional plan without undue distortion due to the whims or vagaries of some planner who is not thinking of the local requirements of the situation, and the regional plan must be made not only by looking at it from the top but by looking at it from the bottom also, and seeing that every local interest in the community is given a chance to be of the utmost efficiency in working out the plan. The foundation of every plan should be the financial plan which will provide the best type of financial structure for each project.

Finally, it should provide for recognition of regional planning bodies by banking sources as advisors, and perhaps endorsers, in order to insure the wisest financing of these projects. Certainly in any regional planning group they should act in an advisory and consultative capacity on the projects which are set up to fit into its program.

To sum up, I believe today, despite surface indications, that our public works thinking is on a better basis than it has ever been. I think we have learned something by the studies of the emergencies of the last few years.

Public works investment will be resumed, and resumed soon. Already the improvements in the municipal bond market and in sources of finance are making themselves felt. Public facilities, wisely designed, are basic because they meet the vital needs of all the people. And generally speaking, in this country they are on a very sound basis. There is no reason to believe that they will not be on an equally sound or even sounder basis in the future with the additional influences that have been brought to bear on them.

The question before us is: shall we profit by this experience, or shall we resume once again the hit or miss progress that we had in the past? Can we not do better today? Shall we recognize the possibility of organizing our public works investment for the future on a basis that will make not only for efficient service to the community but also for a sound and stabilizing influence upon the general economic cycle, of which this is so important a part, and of which I believe it is going to become an even increasingly more important part in the future?

For discussion of this paper see "Public Works and Business Stabilization" by R. S. Meriam, in this issue of the Journal.

A RECENT IMPROVEMENT IN THE CENTRIFUGAL CASTING PROCESS.

BY H. W. STUART* AND S. E. LINDERMAN*.

[*Read September 20, 1934.*]

Centrifugal force has been employed in the production of cast iron pipe for more than eighty years. In the development of the art as applied to cast iron pipe two distinct processes were evolved, due to a difference in the type of mould used. The sand-lined or refractory moulds produced a gray iron casting, but in doing so the mould had to be removed from the machine and was rendered useless. The water-cooled metal or permanent mould produced chilled castings rapidly and in large numbers before being rendered useless, but it was necessary to anneal these chilled castings to make them serviceable. Both of these radically different processes have reached a high state of mechanical perfection in the past twenty years and large quantities of centrifugal pipe are now installed throughout the world.

Recently, it was discovered by Mr. N. F. S. Russell and Dr. F. C. Langenberg, of the U. S. Pipe and Foundry Company, that centrifugal pipe castings could be cast without chill in the steel moulds used in the deLavaud process. The method by which this has been accomplished and the consequent improvement in the quality of the pipe, resulting from this discovery, will be presented in this paper.

Operation of deLavaud Casting Machine. Before describing the process by which chill-free pipe, called "Super deLavaud Pipe," are cast in water-cooled steel moulds, it will be necessary to describe briefly the operation of a deLavaud casting machine.

The deLavaud casting machine, as shown in Figure 1, consists essentially of a cylindrical steel mould, mounted on rollers in a water jacket so that it can be rotated at comparatively high speeds, by an electric motor. The water jacket, in turn, is mounted on wheels so that the entire assembly can be moved by a hydraulic cylinder in the direction of the longitudinal axis of the mould and on a fixed bed inclined slightly to the horizontal. The molten iron is fed into the mould through a trough, also slightly inclined to the horizontal and having at its lower end a spout curved toward the side wall of the mould. This trough is supplied with molten iron by a small ladle of sufficient capacity to make one pipe, and constant uniform flow is maintained, due to the ladle's being tilted at a uniform rate by an electrically operated tilting mechanism.

In making bell-and-spigot pipe, it is necessary to insert a sand core into the bell end of the mould to form the inside contour of the pipe bell,

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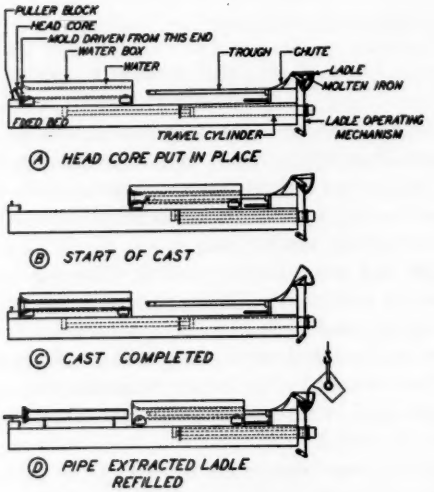
PULLER BLOCK
HEAD CORE
MOLD DRIVEN FROM THIS END
WATER BOX
WATER
TROUGH
CHUTE
LADLE
MOLTEN IRON
FIXED BED
TRAVEL CYLINDER
LADLE OPERATING MECHANISM
(A) HEAD CORE PUT IN PLACE
(B) START OF CAST
(C) CAST COMPLETED
(D) PIPE EXTRACTED LADLE REFILLED

FIG. 1.

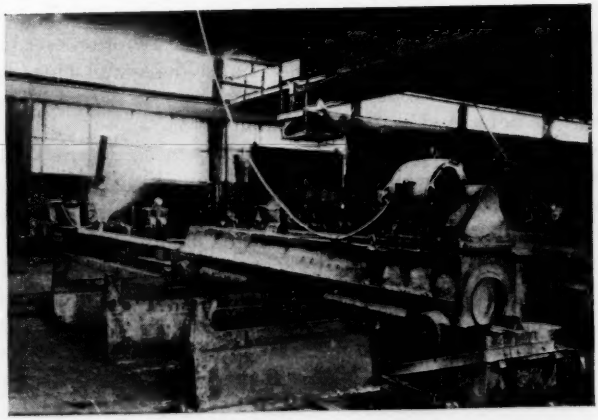

FIG. 2.

and after this has been done at the lower end of the fixed bed, the mould and its assembly are moved to the upper portion of the fixed bed.

When the mould is at the extreme upper end of the fixed bed, it is ready for casting, and the trough extends down the barrel for nearly its full length. After the tilting ladle has been filled by a transfer ladle, from the cupola, the machine operator, stationed at the upper end of the machine, brings the mould up to speed and actuates the tilting ladle. In a few seconds, the iron has filled the bell space and, when this is done, the core setter, stationed at the lower end of the machine, gives the operator a signal to start moving the mould longitudinally down the bed. The stream of iron discharged from the spout flows tangentially onto the surface of the mould, where it is held in place by centrifugal force and forms a homogeneous pipe. The hydraulic cylinder is supplied with a regulated amount of water at a constant pressure; therefore the longitudinal movement of the mould is uniform. Since the speed of the tilting ladle and the amount of water supplied to the hydraulic cylinder can be regulated easily and accurately, the wall thickness of the pipe produced is held within the desired tolerances without difficulty.

After the spigot end of the mould has passed the pouring spout, any excess iron is directed into a pig mould, while the pipe mould is kept rotating at its original speed until the casting therein has cooled to approximately 1 500° F. The casting is then extracted by anchoring it to the puller block and withdrawing the mould. Having withdrawn the pipe, the mould is ready for the next casting. The entire operation requires from two to ten minutes, depending upon the diameter and length of the casting. Pipes in sizes from 3 to 24 in. and in 12-and 18-ft. lengths are now being cast.

The arrangement of the casting machine shown in Figure 1 is purely diagrammatical. Figure 2 is a photograph of a production casting machine, showing the electric drive, used to rotate the mould.

From 1922 to 1934 approximately 85 000 000 ft. of deLavaud pipe were made in the United States by the United States Pipe and Foundry Company, owners of sole rights in this country, and the National Cast Iron Pipe Company, Sub-licensee.

Development of Super deLavaud Pipe. In 1930 a Research Department was established by the United States Pipe and Foundry Company and, shortly after this, it was found that by altering the annealing cycle the quality of the pipe was improved. It was further discovered that in order to attain the impact resistance desired a change in the casting method would have to be made.

The results of the tests conducted in the past indicated that, were it possible to produce a casting without the presence of chill, a greatly improved product would result. Knowing the cause of the chill and having determined that the basic principle of the process, namely, use of the water-cooled metallic mould, was technically and economically

sound, but one thing was left to be done: to provide means for retarding the abstraction of heat from the molten metal. A great deal of thought was given to the application of a refractory wash. There are, however, drawbacks attached to such a procedure. First, it would require a sufficiently long period between the application of the wash and the casting of the pipe to permit the wash to be thoroughly dried. Further, the wash would adhere to the pipe in some places and to the mould in other places with the result that the mould would have to be thoroughly cleaned and rewashed in order to obtain a pipe with a smooth surface. Attention, therefore, was turned to the possibility of applying a dry coating material to the surface of the mould which would either be completely removed with the casting or be of such nature that a jet of compressed air would remove quickly any residue of coating material from the mould.

Since cast iron pipe must have a smooth outside surface, it was necessary to perfect a method by which pulverulent materials could be applied to the mould uniformly and conveniently. In addition, uniformity was necessary in order that cooling of the molten metal be retarded the same amount throughout the casting.

In perfecting a method for applying the pulverulent materials, a great deal of experimenting was required. Some of the early equipment for applying the pulverulent material was built very much on the salt-shaker principle. Other equipment consisted of a trough extending the full length of the mould, which contained the proper amount of coating material, and application and distribution were performed by tilting the trough containing the coating material while the mould was revolving. A screw conveyor which fed the powder through a tube fastened to the trough was also tried, but the nature of most of the pulverulent material is such as to pack very firmly and give the coated surface an unsatisfactory lumpy appearance.

When these mechanical means of distributing pulverulent material failed to produce the desired mould coating, compressed air was decided upon as a means of transporting and depositing a coating on the mould. In the use of compressed air as a carrier and a means of distribution, two problems were encountered. First, a means of feeding the pulverulent material into the air stream at a constant rate in regulated amounts had to be devised; second, a means of uniformly distributing the coating material over the mould surface was necessary.

Figure 3 shows a device which was developed to feed regulated amounts of pulverulent material into the air stream at a constant rate. This device consists of a cylinder, the bottom of which is a turn-table rotated at a uniform rate independently of the cylinder walls. The powder content of this cylinder is made to rotate as a unit by means of a centrally located agitator and clutch teeth on the upper face of the turn-table. The cylinder is slotted at the top of the turn-table and a knife is affixed in the slot so that a constant amount of powder is pared from the uni-

formly rotating column. This knife can be adjusted so that the amount of powder pared off can be varied from 20 to 1 200 grams per minute. A funnel directs the powder delivered by the knife into an air jet. When the air expands, as it issues from the jet, it causes the powder to become

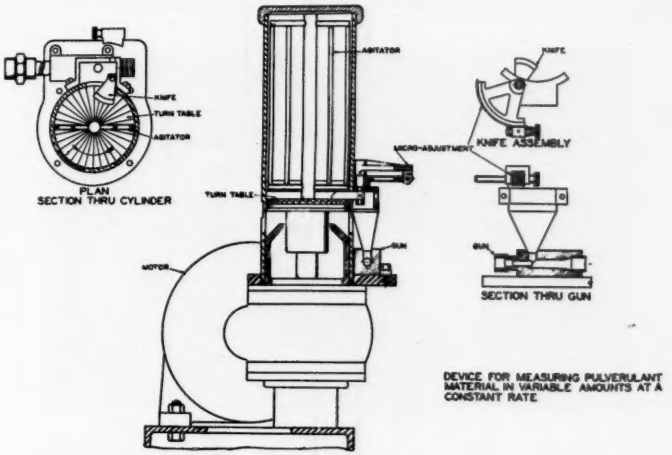

FIG. 3.

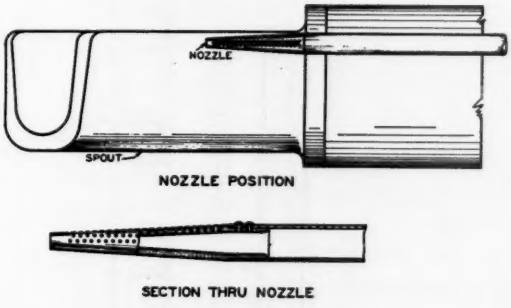

FIG. 4.

suspended in the air stream. The mixture of gas and powder is conducted through a tube which forms an integral part of the casting machine trough.

To distribute the pulverulent material uniformly on the mould surface, the nozzle, shown in Figure 4, was used. One hundred and fifty-seven different nozzle designs were tried before the tapered nozzle shown was adopted. The difficulty in obtaining the proper nozzle design was

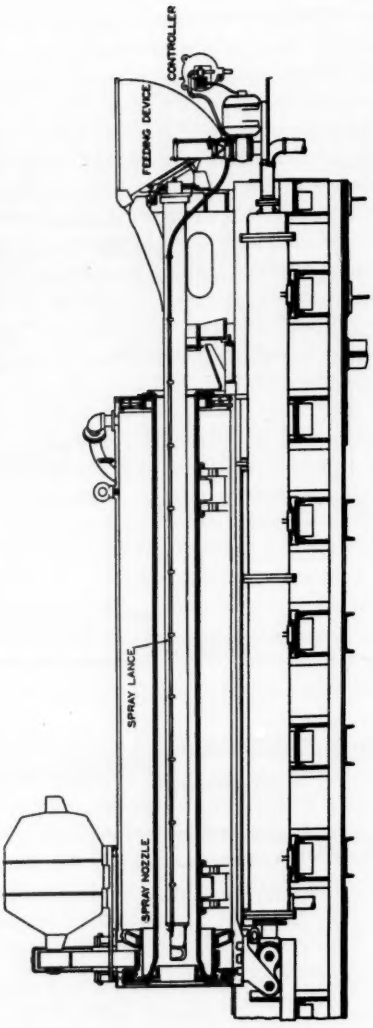

FIG. 5.

due to the fact that the suspended material had to be turned through 90 degrees and, at the same time, distributed over a length of approximately three inches in order that the helix formed as it was applied to the mould would completely cover the surface.

Figure 5 shows a deLavaud casting machine in casting position with the equipment required to coat the main barrel of the mould. It can be

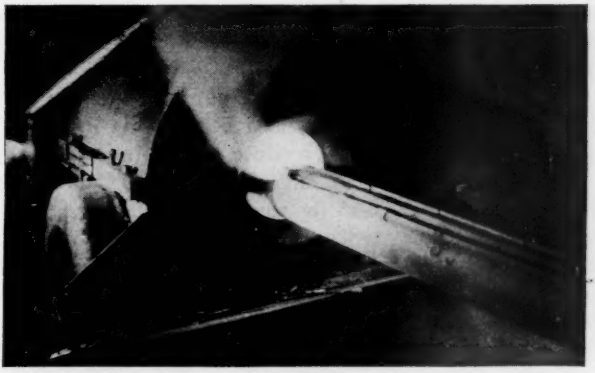

FIG. 6.

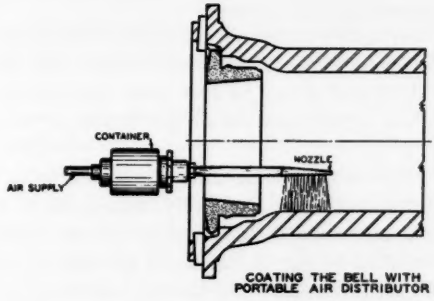

FIG. 7.

seen that the feeding device at the upper end of the machine and the distributing nozzle, located just back of the trough spout, are connected by a steel tube that is an integral part of the trough. This equipment in no way interferes with the normal funetioning of a deLavaud casting operation, since the machine operator actuates the feeding device and air stream simultaneously with the longitudinal movement of the mould as the pipe is cast.

Figure 6 is a photograph of the spigot or upper end of the mould showing the nozzle distributing coating material just back of the trough

spout as it issues from the end of the mould at the completion of the casting operation. The very fine cloud of pulverulent material, which is very clearly shown, is held against the inside surface of the mould by centrifugal force, when the pipe is being cast.

The mould-coating equipment, shown in Figure 5, cannot coat the bell portion of the mould due to the nozzle being behind the iron stream. Figure 7 shows a portable air feeding device and nozzle, which are used to coat this portion of the mould as the bell core is keyed in place. This operation is performed by the core setter without interfering with the casting operation in any way.

As the method of applying a powder uniformly to a deLavaud mould was being developed, progress was also being made in obtaining the proper mould coating material to produce a chill-free pipe with a good surface. It was discovered, early in the experiments with the use of air as a means of transporting and distributing the coating material, that chill-free pipe could be cast with a very small amount of coating material. For instance, a 12-in., 18-ft. pipe could be cast chill-free when only 200 grams of material were applied to the mould during the casting. This was a very novel accomplishment when it was known that it required about one hundred fifty times as much material to effectuate the same chill elimination if the mould coating was applied and distributed in accordance with previously known mechanical methods. The presence of large amounts of pulverulent coating material in a mould also has a very detrimental effect on the appearance of the pipe.

When 200 grams of Ferro-Silicon, one of the pulverulent materials used in this process, are applied to a 12-in., 18-ft. mould, the film of powder is only 0.0003 in. thick and it can be seen from this that such a thin film would not cause the outside surface or dimension to change a noticeable amount.

When a film of Ferro-Silicon 0.0003 in. thick is considered as a refractory, it is found that as such it would be wholly inadequate to retard the heat abstraction from the molten metal a sufficient amount to prevent the formation of chill. The effectiveness of this small amount of coating, thus far, is explainable only on the assumption that the particles of coating material, impelled by the carrier gas against the mould, are surrounded by an adsorbed film of gas and that this film, for an appreciable time after the coating is deposited, forms an effective part of the coating and performs an important function in bringing about the absence of chill and a desirable structure in the casting.

This assumption is based upon the results of many experiments designed to determine the cause of the phenomenal results obtained by such a small amount of coating material. For instance, equally good results were obtained in one experiment where compressed nitrogen was used as a carrier gas in place of compressed air and the air inside of the mould was replaced by nitrogen. Therefore, it was definitely established

that the results obtained were not the result of any particular property of air. It was also shown that if 200 grams of the Ferro-Silicon, which would make it possible to cast a chill-free 12-in., 18-ft. pipe, were added to the molten metal required to cast this pipe, the increase in silicon content would be insufficient to have any effect whatsoever upon its chilling properties, for such an addition would increase the silicon content from 1.80 to 1.82 per cent., and it is known that variations in silicon content from 1.60 to 2.20 per cent. have very little effect upon the chilling properties of the metal. The foregoing observation presupposed that the pulverulent material combined chemically with the molten iron, but this

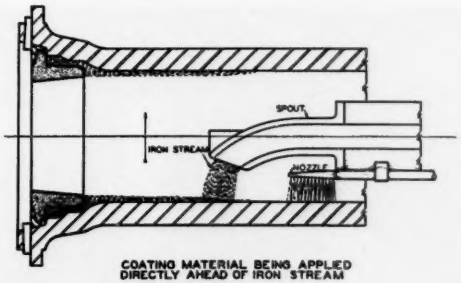

FIG. 8.

is far from the truth for it can be brushed from the outside of the castings and the inside of the mould unaffected in composition and in noticeable amount.

These facts, the well known refractory property of a gas film and observations such as the necessity of applying the coating material at a certain position in the mould just ahead of the iron stream, as shown in Figure 8, led to the previously expressed assumption which will be investigated further in the future.

It has already been explained that the mould coating equipment does not interfere in any way with the normal operation of the deLavaud casting machine. It can also be said that the mould coating material itself does not interfere with the operation for, although it retards the heat abstraction from the molten metal, the difference in the time required for the metal to cool to 1 500° F. at which temperature the pipe is extracted has not been altered appreciably. As a matter of fact, whether or not a pipe contains chill or is chill-free is a matter of split seconds as it cools from its molten state.

It has been found that a number of pulverulent materials can be used effectively to prevent the formation of chill in the outside portion of the pipe wall, and it has also been found that certain materials which will effectively eliminate chill will not produce good outside surfaces.

Before passing from the method of producing chill-free or gray iron castings in a steel deLavaud mould, it should be emphasized that this was accomplished without changing the analysis of the iron used. A typical analysis of the cast iron used is as follows and no so-called graphitizing elements are used nor are they desirable.

Silicon	Sulphur	Manganese	Phosphorus	Total Carbon
1.80	.075	.45	.85	3.65 per cent.

The results of physical tests made on pipes cast experimentally have shown that even considerable deviation from the foregoing analysis, as far as silicon, phosphorous and total carbon content are concerned, does

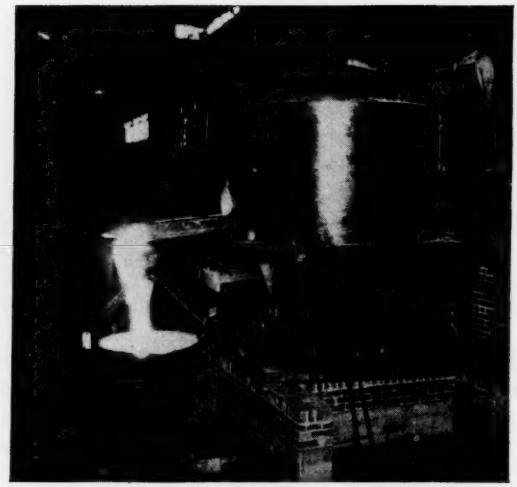

FIG. 9.

not affect the quality of the pipe as much as does the lack of uniformity in cupola operation. In order to insure uniformity of both analysis and temperature, forehearths have been installed at all of the Super deLavaud units. A forehearth, as shown in Figure 9, consists of a refractory lined reservoir capable of holding approximately twelve tons of molten metal, and it serves as a mixing pot in which variations in the speed of melting, iron composition and temperature are reduced to a minimum.

Physical Properties of Super deLavaud Pipe. The production of chill-free castings in water-cooled steel moulds is an interesting subject in itself, but the superior quality of the castings, so produced, is still more interesting to both the manufacturer and the consumer. In order to show the superiority of Super deLavaud pipe, its physical properties will be compared with the physical properties of Standard deLavaud pipe, as it was previously cast directly against the metal mould.

In considering the physical properties of Super deLavaud pipe, let us first consider its properties as it leaves the mould of the casting machine, for it is in the mould of the casting machine that the fundamental metallurgical change in deLavaud pipe has been made. Figure 10, showing the fractures of 6-in. Standard and Super deLavaud pipe in their "as cast" state, makes the foregoing statement evident. It can be seen that Standard pipe has a chill approximately halfway through its wall thickness. Its outside shore hardness is 70 and in this state it is unmachineable, very brittle and quite unserviceable as a pipe. The Super

FIG. 10.

deLavaud fracture shows it to be a gray iron casting throughout. It contains only those constituents that are found in ordinary sand-moulded castings and it has an outside shore hardness of 30. Unlike Standard deLavaud pipe, it is readily machineable and has sufficient impact resistance to be quite a serviceable pipe.

After Standard and Super deLavaud pipe are annealed by the standard practice of heating to a maximum temperature of 1 700° F. and cooling slowly to 1 200° F. in approximately one hour, they both are gray iron castings, having approximately the same hardness throughout their wall thickness. Since annealed Standard and Super deLavaud pipe have approximately the same hardness throughout, due to the reduction of the combined carbon in each to approximately 0.10 per cent. and since they both are cast from metal having the same chemical analysis, a large difference in their physical properties does not seem possible, until the structures are examined under the microscope. Here it is found that, although they are constitutionally the same, their constituents form decidedly different structures, and it will be shown later that these structures have decidedly different physical properties.

Figure 11 shows microphotographs taken from the outside, middle and inside of 8-in. Standard and Super deLavaud pipe, magnified one

hundred diameters. It can be seen that Standard pipe has three separate and distinct structures: an outside structure which was chill and has been reduced to balls of temper carbon in a ferrite matrix, a middle directional dendritic structure which is normal to the outside surface, and an inside graphitic structure which is composed of graphite flakes in a

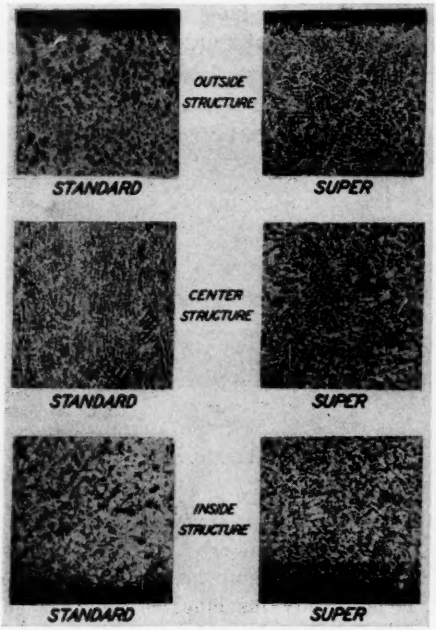

FIG. 11.

ferrite matrix. Super deLavaud pipe has but two distinct structures: a non-directional interlacing dendritic outside structure, and an extremely fine graphitic structure at the middle and inside of the pipe wall.

Dendrites are formed at a rate of cooling slightly less than that which will cause chill and at a rate of cooling slightly greater than that which will cause a graphitic structure to form. Therefore, when the heat abstraction was retarded by the film of coating material on the mould, this structure was moved to the outside of Super deLavaud pipe and, in doing so, it became non-directional. When large amounts of mould coating material are applied, as they were in previously known methods, this unique non-directional structure is not obtained, due to the excessive retardation in cooling the metal from its molten state. It is evident that such a non-directional structure would be very much tougher and resistant

to a force that would rupture it, due to its interlacing nature, than would a directional structure in which planes of weakness are uninterrupted.

This description of the structures of Standard and Super deLavaud pipe is inadequate, but it will have served its purpose if it has demonstrated that, structurally, there is sufficient difference in Standard and Super deLavaud pipe to explain the physical test results reported subsequently. In order to see the real differences between these two structures, it is necessary to study a panoramic view of the entire wall thickness.

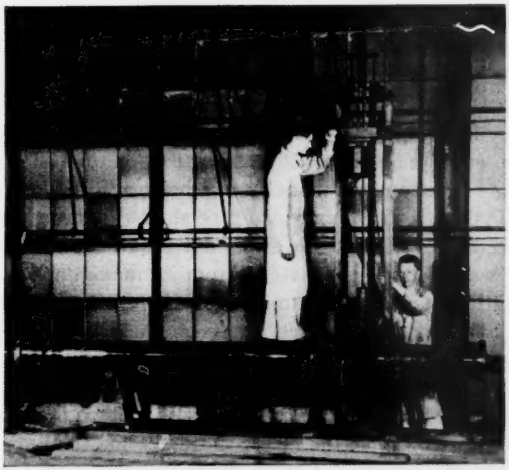

FIG. 12.

The impact resistance of a cast iron pipe is a most comprehensive and reliable indicator of its quality, for impact resistance cannot be obtained without both strength and ductility.

The full length impact test machine, shown in Figure 12, has been used for a number of years in determining the impact resistance of all kinds of pipe. This impact test, or a modification of it, is widely used by cast iron pipe technicians and has proved to be an excellent indicator of the resistance of cast iron pipe to shocks received in transportation, handling and in actual service. The pipe to be tested while under an internal hydrostatic pressure of 65 lb. per sq. in. is submitted to blows from a 50-lb. hammer. The initial blow for a 6-in. pipe is from a height of 6 in. and succeeding blows are from heights increased by increments of 2 in. The pipe is held firmly in 24-in. supports and the blows are all struck at the same point. The number and height of the blows are increased until the pipe fails. The height at which the first crack and first leak appear is also noted and recorded. Three points on a 12-ft. pipe can

be tested in this way since the failures produced do not leak sufficiently to prevent the water pressure being maintained.

Figure 13 is a tabulation of full-length impact-test results on 6-in. Standard and Super deLavaud pipe, unannealed and annealed at 1700° F. These results are typical of the findings in many tests. It can be seen that annealing increases the failure height of Standard pipe from 1.16 to 1.83 ft., which is approximately the failure height of Super deLavaud pipe unannealed. Annealing Super deLavaud pipe increases its failure height from 1.88 to 3.94 ft. In other words, Super deLavaud pipe annealed, as it all is before use, has an impact resistance more than twice that of Standard deLavaud pipe annealed. Let it be further emphasized that these Super deLavaud and Standard deLavaud pipes had the same chemical analysis and that, after annealing, their combined carbons were the same.

The same superior impact resistance of Super deLavaud pipe was also shown by full-length impact tests on 8-in pipe. Eight-inch pipes are tested in the same manner as 6-in. pipes except for the fact that the initial drop of the hammer is made from a height of one foot rather than six inches. Typical tests on annealed pipe show Standard pipe failing at a hammer height of 2.88 ft. while Super deLavaud pipe did not fail until the hammer was dropped three times from its maximum height of 5 ft.

Full-length impact tests not only showed that Super deLavaud pipe has exceptional impact resistance, but also that it has characteristics which are very different from Standard deLavaud pipe. Figure 14 shows the types of failure cracks which were obtained in this test. It will be noticed that the Standard deLavaud failure is a single longitudinal crack which opened up soon after the leak occurred, while the Super deLavaud failure consists of a number of short, tight non-directional cracks which can only be produced by actually indenting the pipe wall by a great deal of pounding after a leak occurs. These types of failure are in accordance with the directional and non-directional structures, shown in the micro-photographs. The ability of Super deLavaud pipe to indent, or otherwise resist localized stress, is shown in Figure 15 at impact points on the two types of pipe. Here it can be seen that the indentation in the Super deLavaud pipe is three times that in the Standard deLavaud pipe.

To experienced pipe line foremen, the impact resistance of a cast iron pipe is readily shown by a few heavy sledge hammer blows. Such a test, although crude, has a great deal of merit and when full lengths of Standard and Super deLavaud pipe are split from end to end with a sledge hammer, the increased impact resistance of the Super deLavaud pipe, as indicated by the full-length impact test, is apparent, not only by the increased labor required but by the fact that the Super deLavaud pipe does not shatter under a heavy blow as the Standard deLavaud does. The difference in the fractures obtained is shown in Figure 16. A 250-lb. hammer was dropped on these 6-in. pipes at the center of a seven-foot span from increasing heights until failure occurred. It will be noticed

FULL LENGTH IMPACT TEST ON 6" STD. & SUPER DELAVAUD PIPE				
PIPE		AVG. HT. OF HAMMER IN FEET AT CRACK	LEAK	FAILURE
STANDARD	UNANNEALED	.94	.94	1.16
"	ANNEALED AT 1700°F	1.66	1.66	1.83
SUPER	UNANNEALED	1.39	1.78	1.88
"	ANNEALED AT 1700°F	2.05	2.72	3.94
WATER PRESSURE 65# INITIAL HT. OF HAMMER .5' 2" INCREM'T				

FIG. 13.

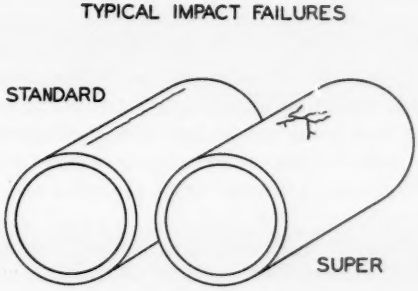

FIG. 14.

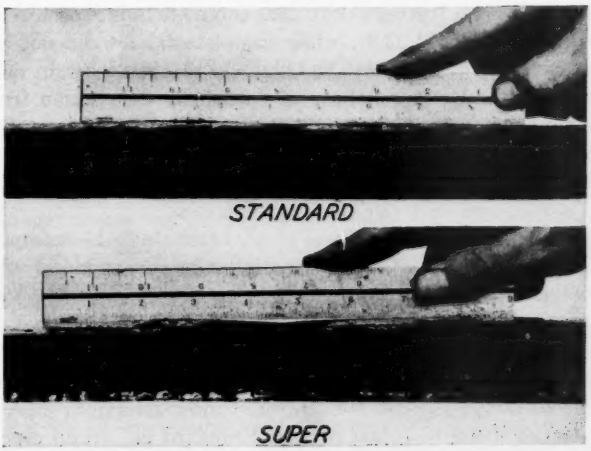

FIG. 15.

that the Standard pipe was rendered useless by shattering, while the Super deLavaud pipe broke off circumferentially and could be repaired with a sleeve.

A cast iron pipe does not usually fail due to repeated blows on a single point. For this reason exception has been taken by some investigators to the repeated blow impact test. This exception has been given consideration, and experiments were carried out to determine exactly what takes place as the repeated-blow impact test progresses. These experiments were conducted in the following manner.

A 12-ft. length of 8-in. pipe was placed on a 10-in. span and struck a single blow with a 50-lb. hammer. The height of hammer for this first specimen was 4 in. The impact point and the height of the hammer blow are marked on the specimen and it is removed from test. This procedure is then continued with other similar specimens, the height of hammer being increased 2 in. for each specimen until failure in a specimen finally occurs. These specimens tested are then heated and dipped in hot tar. The tar enters the internal cracks produced by the impact blows, and after the tar is cooled, the specimens are broken with a sledge hammer through the impact point and the size of the crack is shown by the tar there included. Figure 17 shows an internal crack produced and indicated in this manner.

The size and shape of the internal cracks are recorded in full scale on a section of the pipe wall in the manner shown in Figure 18. It can be seen from these results that the first internal crack occurred in the Standard specimens at a hammer height of 0.5 ft., while the first internal crack did not occur in Super deLavaud specimens until the hammer reached a height of 1.16 ft. It is further shown that complete failure occurred in the Standard specimens at 1.33 ft. while complete failure did not occur in Super deLavaud specimens until the hammer reached a height of 2.83 ft. These Standard and Super deLavaud specimens were taken from pipe cast from the same ladle of iron and in the same mould, the only difference being that the mould was coated in one instance and uncoated in the other. The specimens were also of the same wall thickness and were annealed in accordance with our standard practice.

These results, and the results of many other single-blow impact tests made in this way on pipe of other sizes, indicate very definitely the reliability of the repeated-blow impact test and the toughness of Super deLavaud pipe. It will be noticed that, although the internal crack is formed by blows much less than required to cause failure, this internal crack is not large and is not as easily extended in the non-directional interlacing dendritic outside structure of Super deLavaud pipe, as it is in the directional dendritic structure of Standard deLavaud pipe.

The internal crack single-blow impact test not only shows the superiority of Super deLavaud pipe, it also demonstrates the necessity of handling all cast iron pipe in a manner which will prevent damage that

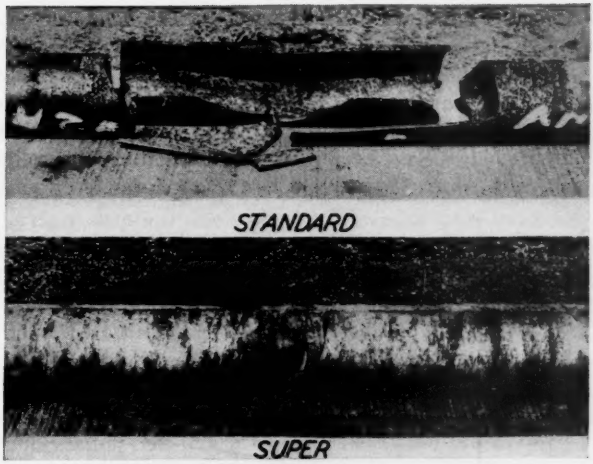

FIG. 16.

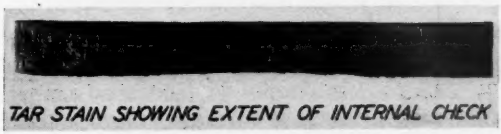

FIG. 17.

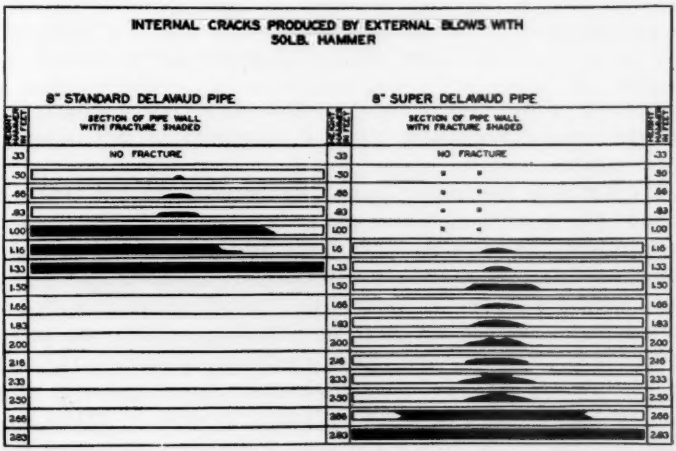

FIG. 18.

cannot be detected until the pipe is called upon to resist an internal pressure sufficient to rupture the remaining portion of the pipe wall. Failures in pipe lines under low pressures have previously been mystifying. Now they can be explained by the fact that some time after manufacture the pipe was struck an external blow, causing an internal crack which extended almost through the pipe wall. Internal cracks, resulting from external impact blows, have been produced in all kinds of cast iron pipe, and the ease with which these cracks can be produced is by no means a

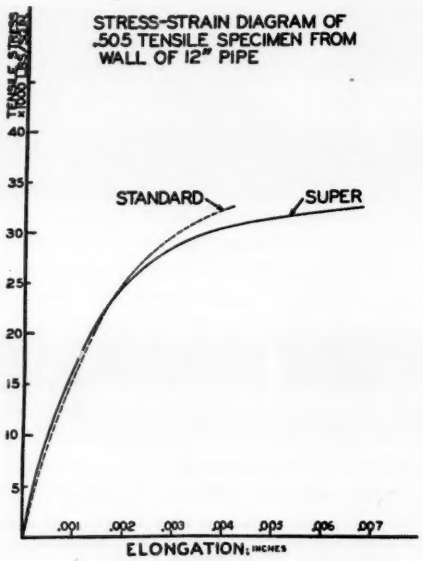

FIG. 19.

characteristic of pipe cast in metal moulds. As a matter of fact, Super deLavaud metal is much more resistant to external impact blows than pit-cast metal.

The foregoing test results have demonstrated the fact that Super deLavaud pipe is much more resistant to handling shocks than Standard deLavaud pipe. As has been stated previously, this improvement is the result of high strength combined with ductility, as shown by the stress-strain diagrams in Figure 19. These stress-strain diagrams show the stress in pounds per square inch and the strain in inches per inch, up to the point of failure of 0.505-in. diameter tensile specimens, taken from the wall of 12-in. pipe. Super deLavaud metal is shown to have 62 per cent. greater elongation and, at the same time, its tensile strength of 32,000 lb. per sq. in. is equal to the tensile strength of Standard deLavaud metal. Bursting-pressure tests also reveal the same high tensile resistance for which Standard deLavaud pipe has been famous.

PUBLIC WORKS AND BUSINESS STABILIZATION.

BY R. S. MERIAM.*

[*Read September 18, 1934.*]

I regret very much that some of my observations are going to be of a somewhat more skeptical character, that I cannot share in all respects the optimism and enthusiasm of Colonel Chevalier.† I shall endeavor to point out that I do not disagree entirely with the Colonel. For example, I trust that any of this poppycock about the inevitable efficiency of public enterprises will be absent from my talk. And I trust that wild phrases about the extravagant handling of other people's money will not have too large a place.

Now, I am not suggesting that public works should not be undertaken. I am not suggesting that public works are not good things. And I am not suggesting, moreover, that public works do not provide employment. But I am engaged in a study of the technical water works operation known as priming the pump.

The object of priming the pump — and incidentally I have actually primed pumps in my time; I know something about that water works operation, and it is one of the few water works operations I do know something about, for as a barefooted boy down in Maine I did it — the object of priming the pump is to get more water than you use as a primer. The hope and expectation of the advocates of public works is not simply that you will provide a certain amount of water and will get a certain amount of good results, but that by so doing you can stimulate normal business and normal employment in private business. In other words, the whole question, as I see it, is whether you will get permanent results; whether, in addition to the immediate effect, the immediate goods you create, the immediate employment you get, you can stimulate the recovery of private business. That is the only controversial issue that I am going to discuss.

This restoration of the normal circulation of money and goods, this restoration of the normal operation of your water system, depends, as I see it, upon certain favorable economic and political circumstances. In the absence of these favorable economic and political circumstances I see little hope that public works will do more than get you your public works and provide the immediate employment.

The first economic condition of successful priming is that the public works program should be inaugurated at the right time. Around 1929 the opinion was often expressed that the proper time to inaugurate a public works program to stabilize business was to start out at the beginning of a

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†See preceding paper in this Journal.

depression, when private employment and private business relaxed, in the hope that the public works would start things going again and thus avoid the depression. That view was expressed by a very distinguished committee of business men brought together by President Hoover, called the President's Committee on Recent Economic Changes, and is to be found in the introduction to the report on Public Works by Leo Wolman, at that time of the National Bureau of Economic Research.

This view — the view that the time to inaugurate public works is at the time the depression starts, at the very beginning of it — in my judgment may be definitely abandoned. The experience of the public utilities and the railroads in making heavy expenditures at the beginning of this depression has shown that the repercussion from such economic activities does not affect the situation favorably. The depression rode roughshod over the feeble efforts of the railroads and the public utilities.

The proper time to inaugurate a program is not, in my judgment, at the beginning of a depression, but at the end of it. At such a time, toward the end of the depression, the bank portfolios are not filled up with bad or slow loans. The credit stringency has passed. The government can finance its undertakings of public works without great difficulty. Business has not yet sufficient activity at such a time so that the government financing interferes with business financing. There are not enough bank borrowers who are worthy of bank loans to be deprived by government competition of any funds they may need.

Equally important is the fact that during the depression, in setting the stage for a recovery, economic adjustments of all sorts have been made, inventories are in good shape, costs and prices have been painfully brought into some kind of line, and some investors and some business men are beginning to think about the industrial expansions necessary to revive the capital goods industries. At such a time, the end of the depression, there is some chance also of a favorable psychological attitude from private business, as well as on the part of the government — confidence, optimism, and courage.

Therefore, the first economic requirement for successful priming of the pump, in order to get a good effect, to provide a real stimulus for your entire economic mechanism, is that the public works be undertaken in a period toward the close of a depression, when the prospects of revival are very good.

A second necessary circumstance is that the government expenditures for public works should be in the right amount. Like other stimulants, a public works program can be too small to be effective; and like other stimulants, or other medicines, it can be so large that it is harmful. If the public works program were limited to the construction of a dam in Washington, most people would agree that it would not be large enough to affect a country of this size. It is in my judgment extremely doubtful if anything like ten billion dollars is necessary to provide a sizable stimulant. In the old days of pump priming down in Maine I learned that if I tried to use

too large a quantity of water most of it spilled out of the top of the pump onto the ground. Large expenditures can throw the government budget so badly out of balance that confidence in the currency is impaired, the prospect of ruinous taxation weakens business enterprise, and the funds are diverted from private enterprise and are no longer net additions to purchasing power. They simply take the place of private additions to purchasing power. Moreover, the administrative difficulty of handling large funds can lead to waste and demoralization. The prospective difficulty of separating large numbers from the government pay roll can well arouse such concern that the stimulant turns into a depressant.

Therefore, I say that the second economic requirement is that the public works must be in the right amount, neither too small to be effective nor too large to be an overdose.

The third necessary circumstance is that the expenditures should be on the right terms. This is one of the reasons for having a public works program of a substantial amount; because the larger the public works program; the more influence it gives the government to affect economic relationships, particularly to affect wage rates and other prices. If the government policy is so permeated by the consumer purchasing power policy that its chief object is to build public works on a high rate of wage per unit, it may set wage rates that hinder the absorption of the unemployed into private industry.

I should add this to what Colonel Chevalier had to say in criticism of our present public works program: I think a considerable portion of the mixture of recovery and relief which the Colonel criticized was due to the fact that this administration thought that by not giving so much stimulus to the capital goods industries, by not using so much machinery, by using more hand labor and relatively inefficient devices, it would stimulate consumer purchasing power.

A large government program gives the government terrific power not only over the salaries paid to the presidents of banks and insurance companies, but over the prices of a very large number of commodities, and gives it a very substantial influence over the rates of wages. I quite agree that if the government program exercises a beneficent influence upon prices and wages, tries to put them in line, it may stimulate the recovery of private business. If, on the other hand, it makes artificially high wages even higher, it can substantially hinder the reabsorption of the unemployed.

Still another condition is moderation to a certain extent in public works in a prosperity period. The government should build up a reserve of worth while projects instead of spending all the money when business is booming. Such moderation will leave government credit and potential tax yields in a strong position. It will also permit the public works projects reserved for the recovery effort to be well designed and socially acceptable. This is an important aid in stimulating private business without alarming it.

These are the economic requirements of a successful priming program.

There is no economic reason, therefore, as I see it at least, to declare that successful priming is impossible. It is not simple. It has to be at the right time. It has to be in the right amount. It has to be on the right terms. It has to be planned ahead along financial as well as technical lines.

The question remains whether these economic requirements can be met as a matter of practical politics. Can our politics, our political machinery, translate these generalities of mine into a detailed program which will fit the particular circumstances — the right time, the right amount, the right terms? Can our political organization produce the requisite combination of restraint and courage? Can public opinion be made sufficiently steady, rational and intelligent?

It is here that, at the risk of appearing to answer in the affirmative Colonel Chevalier's question, "Are you ready to indict the intelligence of the American people?" I come pretty close to it. The question is: Can our political organization meet these economic requirements? It seems to me that under modern conditions, with so many people failing to make the Colonel's distinction between the regulatory and the business activities of government, with universal suffrage, lobbies, and political parties, it is most unlikely that economic requirements can be met. When business is booming it is more likely that our governors will share the illusions of prosperity than that they will be more farsighted than the general public. Can you imagine, for example, a president going into a presidential election and saying, "Gentleman, we have the most magnificent boom in history, but of course it won't last, and I can't take credit for it; we have to be more farsighted than these wild business men and these stock exchange speculators?" I have never heard of a president of either party who was not ready to claim the credit for a boom, or to shift the blame for a depression. Is it likely that in a period of boom, when everybody else is optimistic, our government would exercise that restraint and hold these programs in check? If public works were held in reserve, I am afraid that it is more likely that they would be undertaken early in a depression, to meet the pressure to provide employment, rather than saved for the later period when normal circulation might be restored. Political pressure pays more attention to election dates than to economic conditions.

To meet these economic requirements, a radically different political organization than we now have would be necessary. This sort of economic planning requires that the planners be securely entrenched in their political power, not fearful of being turned out at the next election, able to dominate public opinion. They must be in a position to go ahead and make plans for a long time in the future; be ready to control the situation; not highly volatile. The civil service would have to be highly trained, highly organized, and supremely self-confident. The whole community would have to be tightly knit. The community would have to feel that it was spending its own money, not someone else's. I do not mean by this that the dangers of spending other people's money is any more acute in public business than it

is in private business, but it is always a sensitive situation when people deal with other people's money.

The policy of priming, as I see it, would demand a whole planned economy, something of the nature of a corporative state. In such a state, where you had a bureaucracy, where the civil servants were secure in their tenure, able to develop a professional spirit and able to feel secure in their positions, where there was a substantial amount of planning, where you had no longer the spoils system, where you had no longer the slogan to throw the rascals out,— under such a system the whole business cycle would be radically different. All activities of private business would be substantially modified,— so much so that the business cycle would lose many of its characteristics. For an economic society such as we have in the United States, the prospects for business recovery are greater under governmental economy and balanced budgets than under government expenditures and public works.

Finally let me say a word about the President's program. President Roosevelt's public works program has had lots of luck. He inherited from several years of conservative financial administration a very strong government credit position. By chance, therefore, one of the requirements, that the Federal budget, or the government budget, be not unduly burdened in a period of prosperity, was met.

The second piece of luck was that, as our government had been until this administration a Federal government, not a centralized government, the Federal budget was not heavily burdened with expenditures. Moreover, the President took office at a time when, judged by some things in this country and many things abroad, business recovery was already under way. If President Roosevelt had happened to take office in 1930 and had introduced his public works program, the chances that it would have provided a stimulant to general business recovery are practically nil. The conditions were not right. The pump was not in order and there was no use priming it. The public works undertaken by the telephone and other companies early in the depression had little effect. The Governor of this state is somewhat skeptical about public works, because when he was first elected to office some four years ago he undertook a substantial public works program. He provided us with a beautiful road to Worcester, which took care of a certain amount of employment. It was a good thing, but it did not stimulate general business recovery. There were some pieces of misfortune in the program, but Colonel Chevalier has covered those and I will not repeat them.

On the whole, the President's program was lucky. Despite this good fortune, despite the luck, the results are disappointing. The results of the public works program have been profoundly disappointing. I do not mean that it was wasteful, I do not mean that it did not provide employment; but there has been very little evidence that, as a result, private business has been put on the road to recovery. The numbers of unemployed, the numbers of people on public relief, the prospects for next winter, the

lack of business confidence, all seem to me to negate the claim that the public works program, despite its favorable auspices, has been successful in the sense that it has been an aid to recovery of private business. These disappointing results, in my personal judgment, are to be attributed only to a certain degree to the public works program itself.

I do not believe that this disappointing experience proves conclusively that a public works program cannot stimulate private business. There were some serious mistakes in it, most of which I think are directly attributable to what Colonel Chevalier has said about the capital goods industries; or, as I put it, to the fact that the Public Works Administration was victimized by this so-called consumers' purchasing power policy. If the public works program has been disappointing it is not because of the program itself, but it is because of the consequences of the other economic policies of the administration, either the economic policies adopted by the administration of its own will, so to speak, if you can conceive of an administration ever having a free will, or the economic policies forced upon the administration by great social pressure of half-educated and only partially socialized groups. I do not want to attribute the failure of the public works program solely to the Brain Trust. I think the figures of private employment activities show it has failed in stimulating private business, but I do not believe that this failure should be attributed to the public works program itself. I think it is more largely to be attributed to other policies of the administration.

I might add that what I have said represents my personal views; but unfortunately the differences of opinion among professional economists are very profound, and I sometimes envy the engineers because the engineers seem to have very little controversy among themselves, or at least what seem to us to be very minor disagreements as compared with those which exist among the economists. Relatively speaking, you engineers represent an advanced science.

Discussion of Papers by Willard Chevalier and R. S. Meriam.

COLONEL CHEVALIER. As I listened to Professor Meriam, I recognized that he was saying much better some of the same things that I tried to say in a layman's halting way. In some of the matters on which we disagree, I feel that there is not substantially a great deal of difference.

I am grateful for one thing, however. All of you know as practical men, that every well designed automobile must have two essential adjuncts. It must have an engine and it must have a brake. I gather from what Professor Meriam said that he has cast me for the rôle of the engine, while he assumes that of the brake. And so between us perhaps we can make progress along the road towards a wise administration of public works as a part of our system. I am afraid that temperamentally I shall have to remain in the rôle of the engine.

I have two or three comments. In the first place, I do not believe, being gifted now with hindsight, that any public works program that could have been conceived and sold to the American people in 1929 and 1930 would have been able to pull this country out of the depths into which it had been thrown by the frantic, unreasonable, and predatory speculation of the decade which immediately preceded it. In other words, the American people, in their whole wealth-producing program, had been so burdened down by debts, by speculative debts, by financial manipulation, by excessive capitalization and wholesale issuance of securities based upon a pyramiding of holding company upon holding company, and whatnot, that no addition of further debt within any practical amount at that time would have been able to cushion the inevitable shock that came about from writing off that amount of debt and getting a new start.

Dr. Meriam referred to the beginning of a public works program near the end of a depression. I should like to see the method by which we could determine when we are nearing the end of a depression. I should like to know just how we would time it. In fact, it is very much like floundering in quicksand; it is very much like saying that you do not want to struggle until you are very near the bottom.

In that connection I would emphasize that I have not tried to write a prescription for priming the pump to get out of a depression, especially this depression. That is water over the dam so far as I am concerned. To me it is futile to stand here today and discuss the merits of a program to get out of this depression, or, in fact, to get out of any depression unless by previous control of finance and speculation we put a limit to the excesses that tend to burden our productive industry as it was burdened in 1929. We should be given some practical measure for controlling the financial excesses that affected our business development in that decade. I was speaking more to the point of hereafter organizing our public works program and planning in a way that it might be just what Dr. Meriam suggests, a stabilizer rather than a stimulant.

I agree heartily with what he said about the preoccupation of the administration with consumer purchasing power. In fact, that was the great difficulty which the NRA threw into the picture. The establishment of the NRA held out expectations of increasing wages and employment and thereby purchasing power, and the effect of that increased purchasing power upon consumable goods created a fictitious sense of progress on the part of a great many of our people. I am sure that the administration was bemused by the indicated increase in purchasing power for consumable goods and it completely overlooked for the time being the necessity of effecting a recovery in the capital goods industries, which contributed so mightily to the depression. I think that had a very material effect upon the operation of the program.

I am intensely relieved by one observation by Dr. Meriam. I am glad to know that the country was in such good condition on the 4th of

March, 1933. My recollection is that, if public psychology is any factor in the economic condition of the country, there were very few people in the world who were conscious of our splendid position. In other words, the economic indices and all of the statistics and all of the analyses might have shown a very favorable condition; but I am inclined to think that one of the confusing factors in the science of economics is this very element of human psychology. In other words, the engineer puts his factual values into the equation to determine whether he is on solid ground, but when we take all of the factors which measure the economic position of a nation I am afraid that they are considerably influenced by what the great mass of the people think the conditions are so far as concerns investment and resuming those normal functions which constitute the life of business.

Frankly, the difference between Professor Meriam and me is that I do not believe that the effort along the line of public works administration had such tremendously favorable auspices under which to start. I think that whatever it has succeeded in accomplishing, it has accomplished in spite of great difficulties and great handicaps.

I have only one other thought, and that is, in measuring the success of an enterprise of this kind I do not know how to get a suitable yardstick. It is one thing to say that the public works program has not succeeded in stimulating business; but what I am curious to know — and I know of no one who can tell me — is, what might have happened if we had not done what we did. In other words, it is much more pertinent to measure the results by what might have happened than by any absolute standard of accomplishment. I think that there are persons in this room who know that the public works program has made a substantial contribution toward the recovery of their particular business. How many there are throughout the country I do not know. How to measure that against where they might have been if it had not been undertaken, I do not know. How to measure it against what might have been accomplished with all these other factors to which Professor Meriam so fairly alluded in his discussion, I do not know. There are so many forces acting upon a given point in this setup that it is very difficult to determine how much of the resultant is due to any one of those particular forces.

There is one other thought: That in determining the point at which to launch a public works program as a primer — and again I put the emphasis on the fact that I was not talking about the public works program as a primer but as a stabilizer — I suspect that the tremendous financial influence of the country upon the administration in a question of that sort will never say, "This is the time." The effort of the financial world in a period of deflation is to permit deflation to go just as far as it can but to spare the values that it had created in the previous period of expansion. That is, the deflation must be so handled that the financier and creditor class can hold on and conserve as much as possible of the fictitious values that had been created in the period of inflation. I have grave doubts as to whether the

time would come in the reduction of the debt and in the payment of it that your creditor is willing to say to you, "Now you may go ahead and incur more debts." He is never going to feel that his security will be completely covered so that he will let you go out and begin priming the pump once again by the operation of using credit for investment purposes. Therefore, I can see a number of difficulties in the use of a public works program as a primer to help us out of a depression once we are down in it. I agree with Dr. Meriam thoroughly that that is the time to do it. As he sees practical difficulties in the application of a public works program as a stabilizer, I see practical difficulties in determining the point at which it would be possible, even theoretically, to use a public works program as a primer.

I should like to close as I started, by saying that whatever differences there may be between Professor Meriam and myself on the philosophy of this subject, I am sure they are more superficial than they are substantial, and I could sit down at a table with him, I am sure, and work effectively toward the accomplishment of some measurable result along this line. The only difference would be that I should start out absolutely certain that we were going to get the answer, while he would have to be shown.

PROFESSOR MERIAM. The differences between us are so small that I shall be very brief indeed.

I hope I did not give you a false impression of Colonel Chevalier's position when I said that certain people had advocated public works at the very beginning of a depression. I did not mean to say that that was the spirit or the letter of the Colonel's remarks.

On this question of measurement, what do you mean by success? When I said that the public works program failed, it was simply the statistical fact that private unemployment is still very heavy.

The other question that he raised was the question whether we can ever recognize that a depression is about over, and whether the creditors will ever be ready to say, "Go ahead." I am glad to say that on this point I am somewhat more optimistic than the Colonel. There were many statistical indexes of halting price changes, of halting in the relaxation of private enterprise, that indicated that many of our economic maladjustments had been worked over. I am not so forgetful of the inauguration of the President for whom I once voted that I think that everything was glorious when he took office, but I am inclined to think that the banking difficulties were ripe for surgical treatment that would show prompt results in getting rid of the blood poisoning that was affecting our entire economic life through that very sore spot.

I quite agree, however — although I am somewhat more optimistic than Colonel Chevalier — that the timing, the recognition that now is the time, is, as a matter of political psychology as well as a matter of economic science, an extremely difficult thing. That is one of the reasons why I was skeptical.

I should like to repeat what I said, as I think you may not visualize

what I have in mind. Suppose that your job were at the whim of a highly volatile and changing public opinion. Let us have more water works today; let us have no water works tomorrow. Suppose that in planning for your community you had to plan a program in an economic group that was going to change radically overnight. The thing would be impossible. Let me repeat, therefore, that I think in order to have successful planning of public works we have got to have more stability in our economic life, more bureaucrats, more public servants who are secure in their positions and supported by a public opinion which is not so changeable, not so volatile, without this sweeping out of one party and the sweeping in of another. American public opinion must start out on a long race and not for a 100-yard dash. In order to have a successful public works program we must have a great deal more stability in our economic life and in our political institutions. That involves, I am quite confident, a considerable modification of our political habits. It involves considering order rather than progress. I think we can get ahead farther if we do not try to go ahead quite so fast. I think the old fable of the hare and the tortoise can still be applied, and if you will imagine what would happen to your own planning in your operations if you had a highly volatile market to serve, you will understand the point that I am trying to make.

MODERN ASPECTS OF WATER PURIFICATION.*

BY E. SHERMAN CHASE.†

[*Received October 1, 1934.*]

Pure water, undefiled — demanded by the public, sought by the engineer. For centuries, man has attempted to select sources of pure drinking water guided only by his instinct for a clear and palatable fluid. Less than a hundred years have passed since knowledge and reason began to supplant this instinct, and as knowledge grew, stress was laid upon the selection of supplies free from pollution.

With the advent of population and the development of industry upon catchment areas, sources of pure water became more and more remote. To avoid the cost of long, large aqueducts, methods for the purification of polluted but nearby sources were developed. Furthermore, natural waters, unpolluted by man, often possessed characteristics undesirable in a public supply, thus making necessary the application of corrective treatment.

Many years of scientific study and practical experience on both sides of the Atlantic have developed present day methods of water purification. The water engineers of America owe much to their brethren of the British Isles. Similar, however, as may be the heritage of British and American engineers, the problems relating to water purification in Canada and the United States have had, perhaps, more angles than on the eastern side of the water. This paper, therefore, is an attempt to outline briefly the present state of the art in North America.

Although the scientific basis of water purification in America was established at the Lawrence Experiment Station about 1888 and in Louisville, Kentucky, in 1896, few attempts had been made to utilize such knowledge prior to the beginning of the present century. Three decades ago, the safe water supply was the exception rather than the rule, and the typhoid fever death rate in the United States approximated 35 per 100 000 population each year. In certain cities, like Niagara Falls, the annual typhoid death rates exceeded 100 per 100 000. Only a few of the smaller cities such as Lawrence, Mass., and Poughkeepsie, N. Y., had filters, even for supplies taken from badly polluted rivers. Today not only must public water supplies be hygienically safe, but the public insists on water clear, sparkling, low in color, palatable, reasonably soft and non-corrosive.

Sources of Supply. The sources of supply determine in large measure the methods of purification required. In general, water supplies in North

*Presented before the Institution of Water Engineers at Harrogate, England, June 17, 1931. The lapse of time has necessitated a few changes in the text of the paper as presented.

†Of Metcalf & Eddy, Engineers, Boston, Massachusetts.

EDITOR'S NOTE: This paper is published here in recognition of the agreement reached between the British Institution of Water Engineers and the New England Water Works Association for an annual exchange of a paper.

America are taken from four principal sources: lakes, rivers, impounding reservoirs, and wells. Each type of supply involves individual purification problems. Growths of microörganisms often give trouble in supplies from lakes and impounding reservoirs, and in the Great Lakes, variable and unpredictable currents at times bring gross pollution to intakes ordinarily remote from sources of such pollution. In the case of rivers, heavy rainfall and high run-off cause rapid transportation of pollution from one city to the next. Changing concentrations of industrial pollution result in heavy and varying loadings upon purification works. Ground water supplies, although usually uniform in quality, are generally harder than surface supplies, often contain iron and manganese, and are frequently corrosive. In each instance, the type of purification plant required depends upon the peculiar and individual condition to be corrected.

Selection of Purification Methods. It is obvious that the selection of the type of purification to be employed depends upon the objective to be accomplished. It is also obvious that the primary purpose of water purification is to provide a water safe from the standpoint of public health. Every other consideration must be secondary.

Today the safe supply is taken as a matter of course and the consideration next in importance is undoubtedly the production of water free from objectionable tastes and odors. Coincident with the requirement for palatability is that for freedom from turbidity. The quality of natural waters in the United States varies widely from the generally soft, clear but colored waters of New England to the hard, turbid but colorless waters of the West. Consequently in some sections the removal of color is stressed, and in others the reduction of hardness and turbidity.

In the case of ground waters, the removal of excessive quantities of iron and manganese is important. Furthermore, ground waters are often actively corrosive. In many instances treatment of surface supplies by coagulation and filtration results in a final product of distinctly aggressive qualities as regards action upon metal pipes.

To produce a water having every virtue and not a fault is the problem of the water engineer. The accomplishment of this task involves a complexity of treatment and a variety of methods little dreamed of a generation ago.

Purification Methods.

Partial or Preparatory Treatment. To the triad "old books, old wine, old friends" might be added "old water." One of the most important factors in connection with the safety of a public water supply is the time elapsing between pollution and consumption. Consequently, an ally of the greatest importance is storage, either natural or in large impounding reservoirs. As a result of such storage, distinct improvement in sanitary quality and certain physical qualities results from the settling out of bacteria and other suspended particles; the bleaching effect of sunlight reduces color; and

disease germs die a natural death as a result of unfavorable environmental conditions. The water supplies of Greater New York and Greater Boston are examples of stored supplies in which much benefit is derived from long-time detention in large reservoirs. Up to less than a year ago, the water supply of Boston was subject to no other form of purification than that afforded by storage.

Valuable as is storage, it is an insufficient safeguard against every possibility of dangerous pollution. Depleted reservoirs, short circuits, and accidental or incidental contamination in the vicinity of intakes may result in the complete failure of the theoretical safeguard of long-time storage. It is the almost unanimous opinion of water supply engineers at the present time that all surface supplies, irrespective of storage facilities, should receive additional treatment, at least to the extent of chlorination.

Chlorination, first applied at Lincoln about 1904, by Sir Alexander Houston, has been adopted with amazing rapidity throughout the United States. Chlorination has been employed for many purposes besides that of disinfection. It has been used in connection with the water supply of New York City for the destruction of taste and odor-producing organisms and their products. Super-chlorination and de-chlorination have been used in Toronto, Ont., to destroy tastes resulting from phenol compounds present in the waters of Lake Ontario. At Rochester, N. Y., chlorination in conjunction with permanganate of potash has been used for the same purpose. At a few places in the United States and Canada chlorine and ammonia have been employed to prevent tastes resulting from the use of excessive quantities of chlorine alone. In Kansas City, Mo., chlorine has been used to prevent algae growths in an uncovered distributing reservoir.

In order to lighten the bacterial loadings on filter plants treating heavily polluted supplies such as are derived from rivers like the Hudson, the Mississippi and the Ohio, pre-chlorination has been adopted. Such use of chlorine has lightened filter loads and has kept settling basins from becoming foul. Data indicate that, although pre-chlorination will increase chlorine consumption from one-third to one-half, in many cases the results appear to warrant this increase. Pre-chlorination has also been used to facilitate coagulation and color removal.

Water supplies derived from small ponds, lakes or impounding reservoirs are subject to growths of microörganisms which may give rise to objectionable tastes and odors. The control of such organisms is generally accomplished by the use of copper sulphate. Certain water departments, notably that of New York City, for many years have made frequent microscopic examinations of samples from the reservoirs connected with their supplies. Guided by the results of these examinations, these departments whenever the need is indicated systematically apply copper sulphate to their reservoirs in quantities adequate for the destruction of the predominating type of organism. In the case of small reservoirs, the usual procedure is to place the copper sulphate crystals in burlap bags and tow these bags

from the stern of a rowboat or motor launch. In a few instances, solutions of copper sulphate have been sprayed over the surface of the pond or reservoir.

Where reservoir waters are subsequently filtered, excessive growths of microörganisms frequently interfere seriously with the operation of the filter plants by clogging the sand, thereby decreasing the time between filter cleanings. Under such conditions, the use of copper sulphate not only in the reservoir but in the settling and coagulation basins ahead of the filters brings about marked improvement in filter operation. Copper sulphate, valuable as it is for the destruction of microörganisms after such organisms have become objectionable, is of no value, however, as regards the reduction of tastes and odors resulting from the death and decomposition of these organisms.

Reference has been made to the use of chlorine for overcoming the tastes and odors from organisms. For the same purpose, aëration is frequently employed both with and without other forms of treatment. Aëration not only reduces tastes and odors, but tends to remove dissolved gases such as hydrogen sulphide and carbon dioxide, the former causing objectionable odor, and the latter increasing corrosive qualities. Aëration is almost invariably used as preliminary treatment in the case of iron and manganese removal plants. As an adjunct to filtration, aëration is also frequently provided today for supplies from lakes or reservoirs.

Types of aërating devices are almost as numerous as the engineers designing them. Inasmuch as aëration involves the utilization of head, careful attention must be given to the selection of the type which involves the minimum loss of head consistent with adequate aëration. At present, spray nozzles are perhaps the most popular, although aërating trays, flights of steps, riffle plates, and even compressed air with diffuser plates are also used.

The removal efficiency of aërating devices as regards tastes and odors is impossible of accurate measurement. Observations on the lee side of aërators treating odoriferous waters indicate clearly, however, that substantial removal is accomplished. The removal of dissolved gases, on the other hand, can be readily determined by ordinary chemical analyses.

The development of coagulation by means of chemicals prior to filtration followed necessarily the attempts in the United States to purify the highly turbid waters of the western rivers. Although coagulation is usually employed preparatory to filtration, it has been used in a few instances for the clarification of turbid reservoir waters, even without filtration. Such has been the case at times with the Catskill supply of New York City where some years ago heavy rainfalls at the time of low reservoir stage brought about a marked increase in the non-settling turbidity of the stored waters.

The coagulant most commonly used is sulphate of alumina either alone or in connection with other chemicals. In recent years, research into the chemistry of coagulation has shown the significance of the hydrogen-ion concentration as regards the formation of flocculent precipitates. The

optimum pH for coagulation is much lower than that ordinarily met with in natural waters, and economies in the use of coagulants, theoretically at least, can be obtained by the adjustment of the pH with sulphuric acid. Practically, however, acid for pH control has been used in but few plants.

Other coagulants than sulphate of alumina have been suggested and used. For example, at St. Louis, copperas and lime have been employed as well as alum, and in a few places chlorinated copperas has been adopted.

The details of coagulation practice in connection with filtration are being worked out more carefully and skilfully than ever before. Thorough mixing of the coagulant and the raw water is essential. The present tendency seems to be toward the use of mechanically operated stirring devices, although Nasmith at Ottawa, Ont., has found that with the Ottawa River water the floc was so fragile that agitation was undesirable. At Cleveland, O., Ellms has utilized the principle of the hydraulic jump to secure adequate mixing. The older types of mixing devices consisting of around-the-end or over-and-under baffles are still used to some extent.

For application of coagulating chemicals, solution-feed devices are now less frequently installed than dry-feed machines. The latter type is easier to operate and makes for a neater plant.

At Columbus, O., the coagulant is manufactured at the filter plant from bauxite and sulphuric acid. This process adds to the complexity of the purification plant and has not met with general favor.

Sedimentation basins for settling out the major portion of the precipitate and entangled impurities are ordinarily provided ahead of the filters. The period of detention most frequently used approximates 4 hours, although a range of 2 to 24 hours may be encountered.

Sedimentation basins are usually built of concrete, and in some cases aëration devices are located on their roofs. At Providence, R. I., large earth basins provide sedimentation, and at Watertown, N. Y., a branch channel of the river is used for the same purpose. Tanks equipped with mechanical devices for the removal of deposited solids are now being installed rather frequently, particularly in the Middle West and where sludge from softening processes is to be removed. In the case of some very turbid and highly polluted river waters, preliminary sedimentation is employed ahead of coagulation.

Pre-filtration. There are only a few instances in the United States of pre-filtration. The plant at Poughkeepsie, N. Y., is one example of pre-filtration by rapid filters prior to slow sand-filtration.

American practice as regards pre-filtration is somewhat different from that of the British Isles. British practice appears to be toward the use of rapid sand-filters without coagulation. In America, coagulants are generally employed.

Filters. The design of the early filters in America was based largely upon information gathered by James P. Kirkwood from a study of European practice. These filters were of the slow sand type and were used for purifica-

tion of relatively clear waters in the eastern part of the United States. The earliest successful filter of this type was built at Poughkeepsie, N. Y., in 1872. Today comparatively few slow sand-filters are being constructed in the United States or Canada. This type of filter is not well adapted for treating highly turbid waters or for the extremes of temperatures which occur in Canada and the northern portions of the States. Although preliminary sedimentation will assist in the reduction of suspended solids, the quantity of fine material remaining in suspension after sedimentation tends to promote rapid clogging of sand beds where highly turbid river water is the source of supply.

Slow sand-filters, where suitable, have the advantage of requiring no chemicals for coagulation and on the whole demand much less skilful operation than rapid sand-filters. One of the most recent large installations of slow sand-filters is that at Hartford, Conn., first put into operation about 1922. The earliest American slow sand-filters were uncovered, as at Lawrence, Providence, and Poughkeepsie, but experience with ice formation during the winter soon demonstrated the necessity for covers. No open slow sand-filters are now constructed.

As regards rapid sand-filters, the design follows more or less standardized practice. Filter units consist usually of square or rectangular concrete boxes. Under-drains probably show the greatest variation in design, although the tendency appears to be toward the use of the simple perforated pipe system. Brass strainers, inverted pyramidal hoppers with cement balls, cemented gravel and wooden slats are favored by certain engineers and have been installed at various places.

Where gravel layers are placed over collecting drains, these layers consist of graded gravel ranging in size from ¼ in. to 2½ in. and approximately 18 in. in depth. The sand used at present is probably somewhat coarser than in the older filters, and has an effective size ranging from 0.40 to 0.50 mm. as compared with 0.30 and 0.40 mm. formerly favored. The thickness of sand beds most frequently specified is 30 in.

Rates of filtration follow the old standard practice of 125 m.g.d. per acre, although at Detroit, Mich., the filters have been designed for rates of about 180 m.g.d. per acre. At Detroit, however, the raw water is relatively clear and ordinarily low in bacterial pollution.

Recent investigations at Detroit, indicate the desirability of making provision for higher rates of washing than have generally been allowed for in the past. High rates of washing are particularly advantageous in summer when the water is less viscous than in the winter and when the higher rate of wash is required to produce the necessary expansion of the sand. At certain plants, notably Cleveland, O., rates of washing are regulated largely by the prevailing temperature of the water.

Wash water is provided by means of independent elevated tanks or by wash water pumps equipped with rate control valves for regulating their discharge. Close control of the rate of wash is essential to prevent over-

turning the sand and gravel beds. The use of air to assist in stirring the sand at times of washing is seldom found nowadays except in the older filters. The same is true of mechanically-operated rakes. Some engineers have advocated supplementary wash water systems of perforated pipe immediately above the top of the filter sand to assist in removing tenacious coatings of film and dirt.

Special types of filters have been designed from time to time to meet local conditions. Such special types, however, have met with comparatively little favor for general adoption. Among such types of filters may be mentioned the drifting sand filters at Toronto, Ont., and the semi-rapid type of filter equipped with patented devices for washing the sand in the bed. Clark of the Massachusetts Department of Public Health has devised a slow sand-filter impregnated with aluminum hydroxide, but such a filter has not as yet been adopted by any municipality. The completely enclosed or pressure type of filter is seldom employed for municipal works at the present time. This type is, however, still in favor for industrial purposes and in a few instances has been preceded by enclosed pressure sedimentation tanks.

Perhaps the most notable feature in connection with modern rapid sand-filters is the refinement of design looking toward ease of operation. Among the accessories of well designed plants are automatic control devices, hydraulically operated valves, remote control for pumping equipment, adequate gages, and self-recording instruments. Usually adequate laboratory facilities are provided, and plants are in charge of technically trained operators, capable of supervising details of operation and making the necessary chemical and bacteriological examinations so essential for proper and economical operation.

Taste and Odor Removal. Mention has been made previously of methods for the control of tastes and odors. Of recent development is the use of activated carbon for treatment of waters laden with odor-producing substances, such as phenol compounds. At Cleveland, O., preammoniation of the filtered water prior to chlorination has proved very effective and economical in the prevention of chlor-phenolic tastes. At Minneapolis, Minn., however, chlorine-ammonia treatment failed to control algae odors whereas pre-chlorination was effective. The use of permanganate of potash with chlorine has been used and found helpful at a few American plants. These few examples illustrate the complexity of the taste and odor problem and the fact that methods applicable in one instance may be entirely inadequate in another.

Control of Corrosion. The control of the corrosive qualities of natural or filtered waters is receiving more attention than ever before. The use of lime, soda ash and of sodium silicate has been found effective under certain conditions. Aëration is also helpful. In many municipalities the corrosive character of the water is accepted as inevitable and is guarded against by the use of cement or bitumastic linings for distribution or service pipes. Unfor-

tunately, this measure is of little help to the consumer as regards corrosion of household plumbing.

Water Softening. The lime-soda process is the generally accepted method for water softening. To prevent deposition of lime salts upon filter sand re-carbonation with carbon dioxide is now standard practice. Hoover at Columbus, O., has advocated the return of sludge to the water to be softened. This method offers the advantage of reducing the carbonate hardness to about 20 p.p.m.

In a few cases, the zeolite method of softening has been adopted for public water supplies. Generally, however, this method has been limited to industrial supplies. Hoover has suggested a combination of zeolite and lime softening to secure the advantages of both types of treatment and to permit the elimination of soda ash.

Iron and Manganese Removal. Iron and manganese removal plants follow fairly well standardized methods, namely, aëration, coke pre-filtration, and sand-filtration. Both rapid and slow sand-filters are employed. Lime treatment has also been employed to neutralize the carbon dioxide holding the iron in solution. This method, however, has been used in a limited number of cases only.

Miscellaneous. Special forms of water treatment have been used with certain supplies. At Rochester, N. Y., sodium iodide has been applied to the water supply for short periods during the year to correct an iodine deficiency with the hope of preventing certain forms of goiter. At Daytona Beach, Florida, the removal of hydrogen sulphide and carbon dioxide is accomplished by aëration. Treatment with lime and sodium aluminate, followed by sedimentation alone, accomplishes softening and clarification. Algae growths have been reduced at Louisville, Ky., by the addition of turbidity to the preliminary settling basins at times of clear, raw water. Natural recarbonation of lime-softened but unfiltered water has been brought about at Oberlin, O., by storage in a large open reservoir.

The limiting factors of time and space do not permit a discussion of many other interesting combinations of water purification methods and experience therewith. A review of the published articles dealing with water purification brings afresh to the reader's mind the complexity of the problems involved in supplying pure and wholesome water to the public.

Investigational Work. No paper dealing with water purification would be complete without reference to some of the more recent and important investigational work which has been done in Canada and the United States. The operation of an experimental purification plant by Nasmith at Ottawa, Ont., has afforded practical demonstration of the value of such preliminary investigations.

The studies of the United States Public Health Service of the efficiency of water purification processes as carried out at several typical municipal filtration plants are noteworthy. Of particular interest, however, are the experimental studies of water purification by Streeter of the Public Health

Service. This work has involved investigations relating to the safe bacterial loading of water purification plants, the value of prolonged sedimentation periods, the effect of variations in pH on the coagulation reaction, the benefits resulting from two-stage coagulation, and the effect of prechlorination upon filter plant efficiency.

Other investigators have been and are working on water purification problems. Worthy of special mention is the work of Baylis at Chicago who is carrying on research in a large experimental plant preparatory to the design of a plant for treatment of the entire water supply of the city. At Chicago the most pressing problems are related to coagulation and sedimentation and to control of tastes and odors in a supply derived from Lake Michigan.

Summary. The modern trend of water purification practice is towards uniformly high standards of quality, not only from the hygienic standpoint but also from the esthetic and economic standpoints. Stress is laid upon the production of nearly sterile supplies. Chlorine is being used almost universally for disinfection and its value in other directions is more greatly appreciated than ever before. Special precautions to avoid unpleasant tastes and odors have resulted in numerous combinations of chemical treatment. Activated carbon for taste and odor prevention appears to occupy the center of the stage. Aëration is well established, and its value and limitations are clearly recognized. The chemistry of coagulation and of softening is better understood and more intelligently applied than ever before. Iron and manganese removal practice is comparatively well standardized. Treatment plant designs involve careful attention to details relating to ease and flexibility of operation. In brief, the water works man has at his disposal a wealth of information and a multiplicity of tools whereby he can deliver to his public a water supply clear, colorless, pleasing to the taste, soft, noncorrosive and safe to drink.

Continued investigations and research are bringing to light new truths and are amplifying old knowledge. Modern scientific and technical progress is becoming more and more dependent upon research. This is as true in water works practice as in other branches of engineering. No art or science can become static and continue to serve mankind. Only by keeping water works engineering kinetic can the ideal — pure water, undefiled — be attained.

PROCEEDINGS.

FIFTY-THIRD ANNUAL CONVENTION.

BOSTON, MASSACHUSETTS.

September 18 to 21, 1934.

The following is a synopsis of such parts of the proceedings of the Fifty-third Convention as appear to be of value for the record.

The Fifty-third Annual Convention of the NEW ENGLAND WATER WORKS ASSOCIATION was held at the Hotel Statler, Boston, Massachusetts, September 18 to 21, 1934.

TUESDAY, SEPTEMBER 18, 1934.

Morning Session.

The convention was called to order by President E. Sherman Chase at 11 A.M.

ADMINISTRATIVE REPORTS.

The Annual Reports of the Secretary, Treasurer and Editor were submitted by Frank J. Gifford, Leland G. Carlton, and Gordon M. Fair respectively. (See page 478.) These reports were accepted, on motion from the floor, duly seconded, and placed on file.

The Secretary announced the election on September 18, of the following

Honorary Members:

William James Eames Binnie of London, England, and Frank Alexander Barbour of Boston, Mass.

Members:

Louis Brooks Davis, Superintendent, Water Department, Merrimac, Mass.

Gail P. Edwards, Laboratory Coordinator, Massachusetts Department of Public Health, Boston, Mass.

William Raymond Clary, Sanitary Engineering Division, Massachusetts Department of Public Health, Millis, Mass.

Thomas Joseph Boland, Superintendent, Water Department, Southborough, Mass.

Wilbert Clark Hardy, M.D., Water Commissioner, Haverhill, Mass.

Edward S. McCormick, Superintendent, Water District, New Britain, Conn.

Charles F. Whitman, Jr., Superintendent Water Department, Abington, Mass.

George O. Adams, Massachusetts Department Public Health, Lawrence, Mass.

John D. Annis, Superintendent-Treasurer, Water Company, Colebrook, N. H.

David R. Smith, Superintendent, Portsmouth, N. H.

Harold John Lockwood, State Engineer, Public Works Administration for Maine, New Hampshire and Vermont, Concord, N. H.

Stuart Edward Coburn, Chemist, Wollaston, Mass.

Florence Edward Driscoll, Registrar, Water Works, Haverhill, Mass.

Joseph J. Murray, Water Commissioner, Newton, Mass.

Charles Augustine Maguire, Commissioner, Water Works, Providence, R. I.

James Henry O'Connor, Engineer, Massachusetts Department of Public Works, Roslindale, Mass.

Anthony C. Benjes, Manager of Light, Power and Water Companies, Lebanon, N. H.

Elias A. Mossey, Superintendent, Water Works, Chicopee, Mass.

George G. Shedd, President, L. H. Shattuck, Inc., Manchester, N. H.

Associates:

The Rogers Press, Printing, Dedham, Mass.

Raymond W. Sparling, Owner and Operator of Public Utilities, New York, N. Y.

THE PRESIDENT. The number of members elected this morning reflects to a considerable degree the activity of the membership committee headed by Mr. Esty. I expect that another year will bring forth additional fruit of the work of that committee.

CLOSING OF POLLS AND APPOINTMENT OF TELLERS.

The annual election of officers for the ensuing year is now before us. Unless there are nominations made from the floor, the polls are now declared closed, and for the tellers of election I appoint Messrs. Arthur C. King, Charles W. Mowry and David A. Heffernan of Milton.

Luncheon Session.

PRESIDENT CHASE. I am pleased to have with us at luncheon today a representative of his Excellency, Governor Ely, and his Honor, Mayor Mansfield of the City of Boston. I will ask his Honor to give you an official welcome on behalf of the City of Boston. [Applause.]

ADDRESS OF WELCOME.

By His Honor, Mayor Frederick W. Mansfield.

I am very glad indeed to have been able to greet you here today. I want to thank you for coming here, and inviting me here. This is the first time I have had an invitation to your Association, and I must say with some chagrin that I never knew that there was such an association as this. When your good president told me it was fifty-three years old and entitled

to some respect on account of its age, I felt that I had been neglecting my early education because I did not know of it.

I am very glad, as Mayor of Boston, to welcome you to our city. I suppose, this being a New England association, that you all know Boston probably about as well as I do myself. It is not necessary for me, since you are all neighbors if you are not Bostonians, to call attention to the many historic places and shrines that we have in our dear old city. I am sure that those of you who come here for the first time, or even those of you who have seen them before, will be very much interested, in going through our city and its suburbs, in noticing those places where the foundations of the liberty of our country were first laid.

I have been glancing over your official program, noting the titles of the papers which are to be read. I noticed one that particularly interested me as a public official; that is a paper that has for its title the PWA projects. I do not know what the program of the Association for the convention may be in regard to that, but I do know this,— and I am very glad to say it to you,— that if your Association should succeed in obtaining new projects covering the particular things that you are interested in, such as water works and sewerage works, if you can obtain additional projects from the Federal Government so that more men may be put to work here in Boston throughout the coming winter, it is something very devoutly to be wished, and something that I would give all the power that I have to bring about. We are facing a winter in which we shall need Federal aid, and of course we shall endeavor to get all the Federal aid that we can, but it occurred to me in reading the title of this paper that you are to hear later that possibly there was an opportunity, by presenting plans to the Federal Government, that great public works, which would put a lot of men to work for a long time, might be brought here, and not only to Boston but to the vicinity of Boston, so that the whole community might be aided by it.

I say, and I assure you that it is sincere, that I am very happy indeed to have this opportunity of meeting people who are engrossed in such serious and important works as those which occupy your attention at the moment.

I take pleasure in bringing you the greetings of the City of Boston and in saying that I hope as the years go by I shall have the opportunity of greeting you again, because I think all of your conventions ought to be held here in Boston as long as you are a New England association.

I thank you very much. [Applause.]

THE PRESIDENT. I believe that I am voicing the sentiment of all when I say that we appreciate the kindness and trouble which the mayor has shown in coming here this noontime to greet us.

We are a New England association, and we are also a Massachusetts association. We are very glad to have with us today Dr. Chadwick, who represents Governor Ely and who also represents the Massachusetts Department of Public Health. Dr. Chadwick. [Applause.]

Address of Welcome

By Dr. Henry D. Chadwick, Commissioner, Massachusetts Department of Public Health.

His Excellency, Governor Ely, was unable to be present with you today and asked me to extend to you his greetings. He regretted very much his inability to attend. He is very well aware of the very important work that is being done by your Association. He realizes full well its bearing upon the health and welfare of the people.

The State Department of Health of Massachusetts is the organization that has the oversight and the care of the inland waters of the state. The State Department of Health, formerly the State Board of Health, was organized in 1859,— the first Board of Health in the United States. At that time, and for some years after, its work was largely with the abatement of nuisances. Later the care and prevention of communicable diseases became a large factor in the work. Then the supervision of the water supplies naturally followed.

I notice that your organization was formed in 1882. Mr. X. Henry Goodnough came to the State Department of Health as an assistant engineer in 1886. Mr. Harry Clark came to the State Department of Health in 1889, I believe. Both of those men became eminent as authorities in water supply and its problems. They have taken part, I suspect, many times in the proceedings of your organization. They served, each of them, a period of forty-five years in the State Department of Health. To them is due very largely the fact that we have now such excellent water supplies in the state. Ninety-seven or ninety-eight per cent. of the population of the Commonwealth now has the advantage of a public water supply which is well supervised, so that the water which comes from unpolluted sources remains, as far as possible, uncontaminated until it is used.

In the State Department of Health, in the supervision of these water supplies, frequent chemical and bacteriological analyses are made to determine the purity of the water. Regardless of the care that may be exercised, some errors may take place, and it is very important that this supervision be maintained. During this last year there were two instances in the state where, because of men working on the watersheds of one of the reservoirs which supplies one of the cities of the state, carelessness occurred which resulted in several cases of dysentery among the inhabitants of the city that used that water. Prompt recognition of the cause by bacteriological examination and surveys of the watershed found the cause and led to its elimination. In another community a bacteriological examination was made of a sample of water and showed pollution from human sources, and immediate investigation resulted in finding the discharge of some sewage from a cesspool at some new buildings not far from the watershed. It was not on the watershed, but not far from the reservoir. It caused that pollution. The discovery was made in time to prevent any serious disease. Fortunately

in those two instances the contaminating material which got into the reservoirs did not contain the germs of typhoid fever; otherwise we should have had a very serious epidemic. If for no other purpose than the elimination of typhoid fever, all the expense and work that is being done would be amply justified.

In 1900, or thereabouts, we had in the state from 3 000 to 3 500 cases of typhoid fever every year. In the late summer and autumn and early winter the hospitals filled up with cases of typhoid fever, which, as you know, is a water-borne disease to a considerable extent. There used to be five or six hundred deaths every year. Last year there were 162 cases of typhoid fever in the entire state with 22 deaths, and the death rate, instead of being 24 per 100 000, as it was about 1900, dropped to ½ of 1 per cent. Typhoid fever is practically eradicated from the state. But continual supervision must be maintained, because these sporadic cases of typhoid fever can pollute a water supply if constant viligance is not exerted.

The other water-borne diseases of the dysentery group we occasionally have, but they are of short duration and they occur in instances such as I told you about a few minutes ago.

I appreciate very much the opportunity of being here with you. To the Governor's greetings I wish to add a hearty welcome from the State Department of Public Health. I know that Mr. Arthur D. Weston, Chief of the Sanitary Engineering Division, would gladly show you about our laboratories, show you the methods and procedures in use at the State House, and also at the Lawrence Experiment Station, where you will be able to see whatever studies are taking place.

I hope that your meetings will be of great interest and that the papers and the discussions will be of great value to you individually, and that the communities from which you come will be benefited by your attendance, and also all of New England. As I understand that a third of your membership is outside of New England, the work that you do here, the conclusions you reach here, will extend far beyond the borders of this section of our country.

I thank you. [Applause.]

THE PRESIDENT. Dr. Chadwick, in behalf of the New England Water Works Association I shall ask you to convey our thanks to the Governor for delegating you as his representative at this meeting. Also we convey to you our personal thanks for appearing here yourself for the Department of Public Health.

Afternoon Session.

Victor M. Cutter, Chairman of New England Regional Planning Commission, spoke on "Activities of The New England Regional Planning Commission."

Colonel Willard T. Chevalier, Vice President, McGraw Hill Publishing Company, New York City, spoke on "Public Works for Economic Stabilization."

R. S. Meriam, Professor of Business Economics, Harvard Graduate School of Business Administration, Cambridge, spoke on "Public Works and Business Stabilization."

WEDNESDAY, SEPTEMBER 19.

Morning Session.

A symposium on "Experiences with PWA and Other Governmental Agencies for Public Works Construction" was conducted by Frank A. Barbour, Consulting Engineer and Past President of the Association; T. B. Parker, State Engineer PWA, Boston, Mass.; Arthur D. Weston, Chief Engineer, State Department of Public Health, Boston, Mass.; A. L. Shaw, of Metcalf & Eddy, Boston, Mass.; Warren J. Scott, Director Bureau of Sanitary Engineering, State Department of Health, Hartford, Conn.; Harold J. Lockwood, State Engineer, PWA, Concord, N. H.; Earl Devendorf, Associate Director, Division of Sanitation, New York State Department of Health, Albany, N. Y. Stephen H. Taylor told of his experiences with a PWA job in New Bedford, Mass.

Afternoon Session.

The session opened with a symposium of experiences in New England and New York on "Taste and Odor Control in Public Water Supplies." The participants were R. G. Yaxley, Superintendent of Water Commissioners, Waterford, N. Y.; James M. Caird, Chemist and Bacteriologist, Troy, N. Y.; George C. Houser, Assistant Engineer, Metcalf & Eddy, Boston, Mass., and Gordon M. Fair, Associate Professor of Sanitary Engineering, Harvard University, Cambridge, Mass. Francis H. Kingsbury Samuel A. Agnew, Attmore E. Griffin, William F. Wells, E. T. Cranch, Earl Devendorf, Warren A. Gentner, Fred E. Stuart, Robert Spurr Weston, Elwood L. Bean, Caleb M. Saville, and Linn H. Enslow took part in the discussion.

A paper "The New Filtration Plant at Braintree, Mass.," was read by Robert S. Weston, Consulting Engineer, Boston, Mass.

A paper "Experimental Study of Porous Plates for Use in Filter Bottoms for Rapid Sand Filters," was read by T. R. Camp, Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass. Gordon M. Fair and Robert Spurr Weston took part in the discussion.

THURSDAY, SEPTEMBER 20, 1934.

Morning Session.

Progress Reports were submitted by Elson T. Killam for the Committee on Pipe Line Friction Coefficients, and by Samuel E. Killam for the Committee to Revise Present Form of Summary of Statistics.

A paper "Tuberculation and Incrustation of Supply Conduits and Distribution Mains in Relation to Their Carrying Capacity," was read by Robert E. Horton, Consulting Engineer, Voorheesville, N. Y. J. Walter Ackerman, Gordon M. Fair, Attmore E. Griffin, Elwood L. Bean, Robert Spurr Weston, and Percy A. Shaw participated in the discussion.

A paper "The Water Works of St. John, New Brunswick," was read by Honorable Rupert W. Wigmore, Commissioner of Water and Sewerage, St. John N. B. This paper was discussed by Hugh McLean and Frank A. Barbour.

A paper "A Recent Improvement in the Centrifugal Casting Process," prepared by H. W. Stuart and S. E. Linderman, U. S. Pipe & Foundry Co., Burlington, N. J., was read by Mr. Stuart. Arthur L. Shaw and E. T. Cranch participated in the discussion.

A paper "Status of Cross Connection Regulations," was read by C. W. Mowry, Manager, Inspection Department, Factory Mutual Fire Insurance Companies, Boston, Mass. E. Sherman Chase and J. Walter Ackerman participated in the discussion.

The President read the Progress Report of the Committee on Amendment of the Constitution of the Association.

David A. Heffernan took the Chair and a short discussion on "Frozen Mains and Services" was participated in by W. C. Hawley, Howard M. King, William Naylor, J. P. Miller, and J. H. Reed.

Evening Session.

AWARD OF HONORARY MEMBERSHIPS AND DEXTER BRACKETT MEMORIAL MEDAL.

PRESIDENT CHASE. The greatest honor which this association can confer upon any man is election to honorary membership. We have elected at this convention two honorary members, one of whom is not here tonight, an eminent British engineer, residing in London,— William James Eames Binnie. [Applause.]

WILLIAM JAMES EAMES BINNIE, M.A. (Cantab), Member of the Institution of Civil Engineers (1900), Member of Council of the Institution of Civil Engineers (1927), Past President Institution of Water Engineers (1922–23), Member of the American Society of Civil Engineers (1929), Fellow of the Geological Society of London (1892). Born 1867. Educated Rugby School, Cambridge University and Karlsruhe (Baden).

After three years' pupilage under his father Sir Alexander Binnie, he was engaged from 1893–95 as an assistant engineer on the construction of the Birmingham Waterworks under the late James Mansergh, Past President of the Institution of Civil Engineers. From 1896–1902 he served under Sir Benjamin Baker, first as a Resident Engineer on the Central London Underground Railway construction, and later as Resident Engineer on the Khedival Graving Dock at Alexandria.

Since 1902 he has been in practice as Consulting Engineer in Westminster. Amongst the many works carried out by his firm, Binnie, Deacon & Gourley, formerly Sir Alexander Binnie, Son & Deacon, may be mentioned those for the supply of water to Birkenhead, the Taf Fechan Water Supply Board, Belfast, the Durham County Water Board, Oxford, Coventry, Kano (Nigeria), Singapore and Hong Kong, the aggregate cost being about £10 000 000.

Mr. Binnie has also taken an active part in hydro-electric work, and was employed by the Ministry of Munitions (Great War) and the Water Power Resources Committee in connection with the preparation of various schemes and reports. He was promoting engineer in conjunction with the late C. S. Meik, M. Inst. C. E., for the Lochaber Water Power Bill of 1921, and with W. T. Halcrow, M. Inst. C. E. for the Grampian Water Power Bill of 1929, both of which schemes have since been carried out at a cost of over £3 000 000.

Mr. Binnie served as Advisor to the British Representative on the Central Rhine Commission 1922, as a member of the Ouse Drainage Royal Commission 1925, as Engineering Advisor to the Doncaster Area Drainage Royal Commission 1926, and as one of the three engineers who formed an International Commission on the Aswan Dam Heightening, 1928. He was Chairman of the Floods Committee set up by the Institution of Civil Engineers, and whose Interim Report was published in July 1933. He has frequently been engaged as an arbitrator and as an expert witness.

Mr. Binnie is the author of the following papers:

"Reservoir Storage in Relation to Stream Flow" (with Dr. Lapworth) Inst. W. E. 1913.

"The Cross Hill Covered Service Reservoir for the Birkenhead Waterworks" Inst. W. E. 1916.

"Water Power Problems" Liverpool Engineering Society 1921.

"Utilization of Waterways for the production of Power: its consequences and applications." XIIIth International Navigation Congress 1923.

"Floods with Special Reference to Waste Weir Capacity" (with Dr. H. Lapworth), Engineering Conference Inst. C. E. 1928.

For the proper introduction of the second honorary member, I shall call upon Harrison Prescott Eddy, Honorary Member of this Association and President of the American Society of Civil Engineers. Mr. Eddy. [Applause.]

HARRISON P. EDDY. It is not only an honor but a very great personal privilege to me to have the pleasure of introducing to you an associate in the profession of sanitary engineering for many years and a personal friend.

This member of your Association, a native of New Brunswick, acquired his early engineering experience upon railroad design and construction in Canada, and later in New England. Coming to this country he occupied a position under Past President Desmond FitzGerald of this society of the Boston Water Department. Following that he occupied an important position in the city of Brockton upon design, construction and operation of important work. Later he formed a partnership with Mr. F. Herbert Snow, following which he has been in private practice as a consulting engineer upon many important projects in the sanitary engineering field. He has served not only municipalities in this state and other New England states, but states throughout a large portion of the United States. He has served the state of Massachusetts as an expert in the case before the United States Supreme Court of Connecticut versus Massachusetts, with respect to the diversion of water from the Connecticut River for the use of the Metropolitan District about and in Boston.

If you will bear with me just a moment I want to call attention to what in my mind is the most outstanding achievement with which he has been connected. During the Great War there was a committee engaged in planning Federal war construction, and one day my late partner, Leonard Metcalf, called me on the telephone and said, "We want Frank Barbour to handle the construction work at Camp Devens; will you see that he does it?" Whereupon I called him by telephone. If I remember rightly, that was Thursday afternoon, and the following Sunday he was out at Camp Devens, and he carried through to completion the work at Camp Devens aggregating an expenditure, if I remember correctly, upwards of seven million dollars. And he had that camp ready for the soldiers as soon as the men were sent there. No more loyal and faithful work could be done by any man for his adopted country than was done by Mr. Barbour in connection with that undertaking. I ought to say also that the strenuous work which he there did affected his health for several years thereafter, so that it was some time before he overcame the effects of that difficult undertaking.

Mr. Barbour has been a business man and is president of the New England Pressed Steel Company. His business ability has been evident throughout his engineering career.

He is a member of the Engineering Institute of Canada, of the American Society for Testing Materials, the American Water Works Association, Past President of the Boston Society of Civil Engineers, Past President of this New England Water Works Association, and he is now Director of the American Society of Civil Engineers.

Members of the New England Water Works Association and guests, I take the greatest pelasure in presenting to you Mr. Frank Alexander

Barbour, Honorary Member of the New England Water Works Association. [Applause.]

FRANK A. BARBOUR. I appreciate that the object of this gathering tonight is a dinner and a dance, and not a speech from me. I am embarrassed, for I know, even though you may not know, that I do not deserve the flattering statement made by Mr. Eddy. I have known him for a great many years, and I do not think that I ever knew him to overstress his data to quite the same degree.

No engineer could fail to appreciate the honor of honorary membership in the New England Water Works Association. The only cloud in the situation is a rather insistent and disturbing feeling that perhaps it registers age of service rather than quality. I think perhaps that is the difficult thing to get away from.

I am very grateful for the honor, and I hope that, despite the exasperations of the PWA, I shall be able during the coming years to so conduct myself as to merit your continued confidence. I thank you. [Applause.]

PRESIDENT CHASE. Mr. Barbour, on behalf of the association I welcome you to honorary membership.

We have one other honor which we confer upon able members of the Association: the Award of the Dexter Brackett Medal. I shall ask Mr. Arthur D. Weston to present the medal which the Executive Committee has voted should be awarded for the most meritorious paper presented to this association during the past year. Mr. Weston. [Applause.]

ARTHUR D. WESTON. To those who are not thoroughly familiar with the award of the Dexter Brackett Medal, I would like to state that this medal was made possible by contributions in honor of the memory of Dexter Brackett, for the most meritorious paper which has been published in the JOURNAL during the year under consideration. I think most of you know Dexter Brackett's history, so that I shall not go into it to any extent, other than to say that he was President of this Association in 1889–1890, Editor of the JOURNAL for a number of years, Chief Engineer of the Metropolitan Water Supply, a man well loved by the membership of the Association, and a man probably as greatly responsible for many of our policies of the present time, or more so, than perhaps any other man.

The first award of this medal was made in the year 1916 to Caleb M. Saville. Mr. Saville also received the award again in 1926. Tonight it is my privilege to make the award for a third time to Mr. Saville. [Applause.]

Mr. Saville, it is a habit, I find, among the membership of this Association, to make this award to you. I can assure you, sir, that your paper was very, very much worthy of the award, and in presenting it to you I want not only to congratulate you but I want to congratulate the New England Water Works Association for having had such a splendid paper. [Applause.]

CALEB MILLS SAVILLE. It is with genuine appreciation of the honor which it represents that I take from your hands the Dexter Brackett

Memorial Medal. I also value highly the kind thought expressed by my friend. When the notice of the award for 1933 came, although I recalled the gratification with which similar honors had been received from you, I regretted that the rules of the award precluded mention of other papers given during this period.

I am of course greatly pleased that my paper was found to contain matter of value in its application to general water works problems. The subject of hydrology in its relation to the water supply is, I believe, worthy of much greater attention than it has received heretofore, and I hope that this Association will devote time to this subject. I wish, however, to emphasize the fact that whatever there may be of intrinsic value in this paper was made possible only through the loyal and painstaking interest of my associates in the Hartford Metropolitan Water Bureau.

This medal is particularly prized by me because of my close personal association with Dexter Brackett, whose name and work it commemorates. Those of us who had the privilege of working with Mr. Brackett will not forget his kindly and helpful ways, as well as his ability and the hewing to the line in all things.

I am further pleased to have this honor from this Association, for it was the first of the technical societies which I was privileged to enter, and of the many with which I am now connected the New England Water Works Association has always held first place in my affection. As I was the first to receive this award, it is particularly gratifying to feel that I am still counted in the long line of men since that time, many of them with national water supply reputations, who have continued mightily to advance their profession and have received this honor at your hands.

I thank you most sincerely for the medal and for the commendation for which it stands. [Applause.]

PRESIDENT CHASE. Mr. Saville, I wish to assure you, on behalf of the Association, that we are pleased indeed that you have received it.

FRIDAY, SEPTEMBER 21.

SUPERINTENDENTS' ROUNDTABLE.

Mr. David A. Heffernan, Past President of the Association and Superintendent of Water Works, Milton, Mass., in the chair.

Thomas E. Lally, Water Division, Public Works Department, Boston, spoke on Spacing of Gates and Hydrants with Particular Reference to their Insertion in Old Distribution Systems. Percy A. Shaw, H. L. Clark, Roger G. Oakman, Sidney S. Anthony, Henry T. Gidley, J. P. Miller, Howard M. King, S. G. Wylie, and Hugh McLean took part in the discussion.

Harold W. Griswold, Deputy Chief Engineer, Water Bureau, Metropolitan District of Hartford County, Hartford, Connecticut, read a paper "Metering," offering for discussion the proposed rules for the Connecticut

water companies prepared by the engineering staff of the Public Utilities Commission of the State of Connecticut. H. J. Cook, Theodore L. Cate, Frank S. Taylor, J. H. Read, W. C. Hawley, and Hugh McLean participated in the discussion.

A paper "The Action of Water on Materials for Service Pipes," was read by F. Wellington Gilcreas, Division of Laboratories, New York State Department of Health, Albany, N. Y. Arthur V. Harrington, Assistant Engineer, Massachusetts Department of Health, read a paper "Materials to be Used for Service Pipes." These papers were discussed by William Naylor, J. Walter Ackerman, Thomas E. Lally, Samuel H. MacKenzie, Linn H. Enslow, and Honorable Rupert W. Wigmore.

A paper "Freezing and Thawing of Water Mains and Services," was read by Albert A. Ross, Superintendent of Water and Sewer Department, Lexington, Mass. This paper was discussed by Howard M. King, William F. Sullivan, Frank J. Gifford, J. H. Read, J. P. Miller, Francis H. Kingsbury, Percy A. Shaw, F. Wellington Gilcreas, Donald C. Calderwood, and Anthony C. Benjes.

William F. Sullivan, President, Pennichuck Water Works, Nashua, N. H., spoke on "Responsibility of Water Utility for Collapse of Hot Water Boilers, Resulting from Drop in Main Pressure." Several stereopticon pictures were shown and explained by Donald C. Calderwood. J. H. Read, J. Walter Ackerman, Frank J. Gifford, Sidney S. Anthony, H. L. Clark, and Hugh McLean took part in the discussion.

A paper "Joint Use of Service Trenches for Different Utilities," was read by Leon A. Goodale, Water Commissioner and Registrar, Worcester. Francis H. Kingsbury discussed the paper.

Report of Tellers of Election.

The Tellers of Election submitted the following report:

Total Number of Ballots Cast	170
Blank	2
For President, HOWARD M. KING	166
For Vice-President, HARRY U. FULLER	167
For Director, PERCY A. SHAW	166
For Treasurer, LELAND G. CARLTON	167

(Signed) ARTHUR C. KING,
C. W. MOWRY,
D. A. HEFFERNAN.

Secretary Gifford announced the election by the Executive Committee of the following:

Members: John J. Healy, Jr., Chemist, Water Works, Newton, Mass.; Walter Benjamin Bushway, Assistant Superintendent Water Department, Brookline, Mass.

Associates: Republic Steel Corp. (John G. Ross), 250 Stuart St., Boston, Mass.; Johns-Manville Sales Corp., 75 Federal St., Boston, Mass.

PRESIDENTIAL ADDRESS.

By E. Sherman Chase, Retiring President.

Membership. One of the outstanding things that your President can report to you at this meeting is the remarkable way in which the strength of the Association, as measured by its membership, has held up during these past four very difficult years. While it is true that the Secretary's report shows a net loss of about five members between September 1, 1933, and September 1, 1934, the Executive Committee (at this convention) has acted favorably upon some twenty-six applications. Last year at the convention the Executive Committee elected ten new members. So that measuring the strength of the Association as from end of convention to end of convention, we have had a net gain during the past twelve months of eleven. We now have a membership of 819.

This membership approaches the maximum strength shown by the Association since the peak in 1916, when the Association had over one thousand members. From that time on the membership dropped until 1925, and then increased to a peak of 830 in 1929. In 1930 it dropped to 822, in 1931 to 816, in 1932 to 809, in 1933 to 798, and at the beginning of this convention to 793. But, taking into account the unusually large number elected at this convention, you will see that we have now started on the up swing of our membership curve.

Deaths. Another thing that is interesting but saddening is the roll of deaths of our members which occurred last year. We lost an unusually large number by death, and we lost very eminent members. We lost two of our honorary members — J. Waldo Smith and Sir Alexander Houston — both of whom were outstanding members of the water works profession. We also lost men like George W. Fuller, a man whose life was concurrent with the rapid advance in water purification.

Finances. Financially we have come through the depression in excellent shape, although this past year, due to somewhat larger cost of publication of the JOURNAL, also due to the fact that we have moved our headquarters from Tremont Temple to the Statler Building, we spent four or five hundred dollars more than our current receipts. But due to the prudence of my predecessors we had an excellent cash balance to start the year. We now have invested funds of over $17,000, and there is no reason to anticipate any drain on those funds. In some slight justification of our expenditures during the past year, I do wish to point out, not as a matter of apology but as a matter of fact, that the expenditures of the past year, except for furnishing the new quarters, were all within the budget appropriations of the Finance Committee.

Meetings. In addition to the usual number of meetings in Boston during the past year, there have been two additional meetings held outside of Boston,— one in Greenwich, Conn., and the other in Manchester, N. H. Both of these outside meetings were eminently successful, drawing from our membership in the vicinity of those two municipalities.

The policy of holding meetings outside of Boston — and by that I mean the one day monthly meetings — will undoubtedly be continued. Certainly at least one of such meetings will be held, and very likely two. This policy will permit visits to the smaller New England cities, which are always anxious to have the convention but in which hotel facilities are not suitable for conventions.

The winter meetings were very well attended also, in spite of the trying winter conditions, and in spite of the special emergency work being carried on under relief measures in so many municipalities, making it very difficult for the superintendents to get away from their jobs.

Journal. The JOURNAL has continued to be of high standard of excellence. We have had good papers during the year, particularly one published in the June issue, prepared by Mr. Kennison of the Metropolitan District Water Supply Commission, describing the work being carried on in connection with the Swift and Ware Rivers extensions. Our JOURNAL is a publication of which we should be proud, both in the character of material published and in its physical makeup. It is the medium by which we are known and judged outside of our immediate New England region.

Committees. The matter of committee work during the past year has not been as fruitful nor as active as in some other years in matters relating to technical problems. The committee work, however, has, I think, been somewhat more active in matters pertaining to affairs of the Association. There have been a number of problems connected with the administration of the Association which have involved considerable study on the part of special committees appointed by the executive committee. We had in the early portion of the past year a committee coöperating with the National Recovery Committee for Water Works Construction of the American Water Works Association. We have had other joint committees with that association, and with the American Standards Association in connection with standard specifications.

You have heard the progress report of the very important committee upon frictional coefficients in water pipe. This is a very able committee under the chairmanship of Mr. Elson T. Killam. In order for that committee to best serve the Association and the water works profession it must secure the wholehearted coöperation of every member of this Association in the matter of compilation of data useful to the committee.

Water Works School. The water works school was carried on this year as in the past two years. This school was established in 1932. It has been conducted at Cambridge with instructors from the staffs of the engineering schools at Harvard and at Technology. In the past it has been customary to hold the school in the winter, but the extraordinary winter, with the difficulties encountered by nearly every superintendent due to the freezing of water mains and services, made it seem inadvisable this year to carry out that policy of holding the school in the wintertime, and consequently it was not held until June. June is a month in which construction activities are just

getting under way, or are in such a stage that it is difficult for the superintendents to get away for any length of time, consequently the water works school this year was rather poorly attended. As a general thing it does seem advisable to hold the school in the wintertime. It seems desirable also for more of our superintendents to attend this school and get the benefits which arise therefrom. As a matter of fact, it costs the Association for the conduct of this school considerably more than it is reimbursed by the small registration fees for the attendance. I feel that this school, however, is well worth while, and that as time goes on it will be more and more important, and that eventually it will be self supporting. We do not care to make a profit with the school but we do want, if possible, to make it self supporting, or very nearly so.

Legislation. As far as I can recall there was only one piece of legislation this past year in which the association was interested, namely, the bill introduced into the Legislature of Massachusetts which, although aimed at the Metropolitan District Commission, would have opened up great ponds throughout the Commonwealth, used as public water supplies, to recreational use, and would have precluded any prosecution for infringement of existing laws designed to protect the purity of our water supplies unless the recreational use of the ponds could have been shown to be pollutional in fact as well as in theory. As you know, it is very difficult in many instances to prove pollution in fact resulting from recreational use of water supplies. The Massachusetts membership of the Association was circularized and requested to get in touch with their local representatives and with the committee of the Legislature to which the bill was referred and protest against the bill. It is unquestionably true that the action of the Association helped very much in keeping this bill from being reported out of committee.

Relations with Other Associations. One of the important matters which is involved in the carrying out of the activities of this Association is the relation of this Association to other associations with allied or similar aims. As usual, we have received the coöperation of the Water Works Manufacturers Association in the matter of entertainment at the convention and in other matters. We have coöperated with that association in holding our convention at a locality and in an hotel with suitable accommodations for exhibits.

We have continued this past year with financial support and with assistance of some of our members in carrying out jointly work of the American Standards Association and the American Water Works Association, as regards standard specifications for water works materials.

We have continued our membership in the Engineering Societies of Boston, now the Engineering Societies of New England, and assisted in the work of that affiliation, but have, as you know, separated from the affiliation in so far as joint responsibility for the maintenance of quarters and personnel is concerned.

We have effected an arrangement with the Institution of Water Engineers of England to exchange papers from time to time, the papers to be prepared by some designated member of each association for publication in the journal of the other. The Institution of Water Engineers has designated Mr. H. J. F. Gourley, consulting engineer of London, to write upon the effect of the very serious drought now prevailing in England upon the storage practice in water works systems of the British Isles; and Professor Gordon M. Fair of this association has been designated to prepare the exchange paper which will be upon some subject yet to be announced.

Divot Diggers. Perhaps one of the interesting developments of the past year designed to further social intercourse both at the time of the convention and during the long summer vacation between the last spring meeting and the September convention is the formation of an informal organization of golfers and near-golfers known as the Divot Diggers. The activities of this organization were in evidence yesterday at the tournament and at the banquet last night, when the prizes were given out by the president of that group, Mr. Roger Esty.

New Quarters. The establishment of the new quarters in the Statler Building, with the engagement of a full time, trained assistant to the secretary, marks a progressive step, and it is confidently anticipated that this move will make the Association much more useful to its members and will furnish quarters attractive and dignified, and in full keeping with the best traditions of this Association.

Publicity. Another advantage in engaging a full time assistant to Mr. Gifford and in engaging an assistant who has the qualifications which she has, is that we have been able to secure in the newspapers far greater publicity for the Association than has ever before been possible. The publicity that we have received is not designed just for the sake of publicity, but it is for the purpose of bringing to the water works superintendents and officials of New England the fact that there is an energetic organization carrying on in connection with water works activities, so that those superintendents who are not members will feel constrained to apply for membership. It is not so much that the Association needs these additional members — we are strong both in numbers and in our financial resources — but it is that these superintendents who are not in the Association need us, and in so far as we serve these superintendents we are serving the public who are served by the superintendents.

Papers by Superintendents. Need has long been felt for superintendents in charge of water works systems to present papers of practical value from the standpoint of operation and management. You have heard the report of the committee on the Amendment to the Constitution, of which Mr. Arthur D. Weston is chairman, in which he referred to the need of an award for the most meritorious practical paper submitted during the year by water works superintendents or other water works officials. Nothing yet has been done on this suggestion, but I feel quite confident that some

step will be taken in the near future to take care of that suggestion. One of the difficulties with which every program committee is faced is this matter of securing papers and discussions from the practical operating men. There is not a water works superintendent in our Association who does not have, sooner or later, experiences different from those of every other superintendent, or who has not solved some problem in a unique way, which, through his own modesty, he feels is not of any consequence and not worth bringing to our attention. If the superintendents would get over that unwarranted feeling of modesty, it would help the Association immensely in the round table discussions such as Mr. Heffernan has so successfully led at this convention.

Recommendations. It is customary for the retiring president to offer suggestions based upon his experience. I have few to offer myself, because I have been trying for the past year to carry out the suggestions and recommendations of my predecessors, particularly those of Mr. Finneran. I would suggest that those of you who have not read Mr. Finneran's presidential address, or who have forgotten it, go back to the JOURNAL of December 1931 and read it. Mr. Finneran, among other things, urged that there should be more life, warmth, and continuity of activity in the Association.

We must continue to carry out efforts to secure new members. There has been during the past year a committee on the securing of new members, headed by Mr. Esty, which has laid the foundation for still further activity in this connection, and the result of the activity of that committee, and of the interest of the members of the Association who are not serving on that committee is shown by the large number of applications which have been received and acted upon at this convention.

In the matter of the JOURNAL,— we must continue to maintain, and even enhance, the high standard of the papers for which the JOURNAL has long been noted. The reputation of this Association outside of New England and the northeastern portion of this country and the southeastern portion of Canada, is based wholly upon the character of the JOURNAL, the character of the papers presented in the JOURNAL, the character of the committee work carried on by the Association, the results of which are published in the JOURNAL. We cannot for one moment let up on the quality of the JOURNAL.

The Association must do all in its power to improve the status of the water works superintendent, and by advocating tenure of office and freedom from political influence the Association must help the individual superintendent to feel sure of his job so long as he does his work well and faithfully. We must resist every effort to make the office of water works superintendent a matter of political fortune. Happily the New England States on the whole have a splendid record in this respect. Once a man is superintendent in a New England municipality, the chances are that he will always be the superintendent so long as he wishes to remain there. Here

and there we find isolated instances of the unfair ousting of a superintendent, but those instances are few. However, as someone remarked yesterday in connection with the sanitary protection of water supplies, eternal vigilance is necessary, and this Association must be ready to prevent any unfair treatment of any of our members, or, in fact, of any water works superintendent.

Furthermore, the water works superintendent should be given recognition for the responsibility which is his, and his salary should be commensurate with that responsibility. There I cannot say that we have anything to be proud of in New England. I doubt if there is a superintendent in our Association who receives the compensation that his services warrant. The Association, by bringing to the attention of the public the value of the work of the superintendent, the tremendous debt owed by the public to that superintendent and his staff, will eventually, I believe, improve the status of the superintendent.

The Association should be ready to participate in public affairs in a more positive manner than has been the case in the past, such as participating, in so far as it is proper, in such matters as regional planning and by the presentation of the facts relative to the water supply and water supply problems to civic and educational organizations.

Conclusion. Serving as your president during the past year has been a very pleasant task. I shall always look back with pleasure to the year which, as far as my tenure of office is concerned, now ends.

In closing I wish to thank the Association, and particularly our worthy Secretary, for the assistance which has been rendered me. I hereby declare the close of the Fifty-Third Annual Convention of the Association.

[Adjourned]

Annual Report of the Secretary.

Mr. President and Gentlemen of the New England Water Works Association,— The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 793, constituted as follows: 12 Honorary Members, 670 Members, 95 Associate Members and 16 Corporate Members. The detailed changes are as follows:

MEMBERSHIP.

September 1, 1933.	Honorary Members	11			
	Withdrawals:				
	Died	2	9		
	Elected:				
	September, 1933		3		12
September 1, 1933.	Members, Total		677*		
	Withdrawals:				
	Resigned	14			
	Died	15			
	Elected to Honorary Membership	3	32	645	
	Elected:				
	September, 1933	6			
	November, 1933	4			
	December, 1933	2			
	January, 1934	2			
	February, 1934	1			
	March, 1934	3			
	May, 1934	7		25	670
September 1, 1933.	Juniors, Total		0		
September 1, 1934.	Juniors, Total		0		0
September 1, 1933.	Associates, Total		95		
	Withdrawals:				
	Resigned	4			
	Dropped by Executive Committee	1	5	90	
	Elected:				
	September, 1933			5	95
September 1, 1933.	Corporate Members, Total		15		
	Elected:				
	May, 1934		1		16
September 1, 1934.	Total Membership				793
September 1, 1933.	Total Membership				798*
	Net Loss				5

*Corrected figure.

Elections.

Honorary Members.

September 20, 1933. William W. Brush, William F. Sullivan, Robert S. Weston. (3)

Members.

September 19, 1933. Frank S. Brainerd, Mark F. Croker, Warren A. Gentner, Paul D. Mallay, Harrison E. Miles, Arthur A. Woodford. (6)

November 8, 1933. Joseph C. Knox, Ralph M. Palmer, Thomas B. Ray, Lewis C. Sanborn. (4)

December 13, 1933. M. N. Baker* and J. Arthur Jackson. (2)

January 10, 1934. Lorenzo B. Fortin and Alfred A. Lamarine. (2)

February 14, 1934. William J. McCarthy. (1)

March 21, 1934. Ralph Adams, George B. Mebus, Fred O. Walker. (3)

May 23, 1934. Robert F. Campbell, Charles W. Easter, Frederick E. Green, Augustus J. Masefield, Harry G. Northrop, George A. Reed, Harry P. Reynolds. (7)

Associates.

September 19, 1933. Baldwin-Southwark Corporation, Roy S. Barker,* Cambridge Machine & Tool Company, Jenkins Brothers,* Vogt Brothers Manufacturing Company.* (5)

Corporate Members.

May 23, 1934. Laconia Water Company. (1)

Resignations and Deaths.

Members.

Resigned: G. F. Ashton, D. V. Bell, A. B. Conant, E. A. Ekern, I. H. Henderson, H. F. Howland, T. A. Kelley, U. S. Lambert, E. Manahan, W. E. Moore, E. A. Northey, G. H. Nye, A. Orr, L. B. Smith. (14)

Died: G. A. Adams, H. F. Dunham, C. W. Ellis, Jr., G. W. Fuller, G. E. Gomley, E. W. Kelly, L. H. Kunhardt, E. L. Neubling, F. V. Pitney, C. R. Preston, J. L. Rice, A. L. Sawyer, C. D. Sharpe, M. R. Sherrerd, W. Wood. (15)

Honorary Members.

Died: Sir Alexander C. Houston and J. Waldo Smith. (2)

Associates.

Resigned: Cohoes Rolling Mill Company, Gamon Meter Company (consolidated with Worthington Pump & Machinery Company), General Pipe Cleaning Company, Inertol Company. (4)

Dropped by Executive Committee: Waldo Brothers & Bond Company. (1)

*Reinstated.

RECEIPTS FOR THE FISCAL YEAR, SEPTEMBER 1, 1933 TO SEPTEMBER 1, 1934.

Entrance Fees			$108.00
Annual Dues:			
Members	$3 290.06		
Corporates	150.00		
Associates	1 580.00	$5 020.06	
Fractional Dues:			
Members	31.50		
Corporates	5.00	36.50	
Past Dues:			
Members	86.00		
Associates	60.00	146.00	
1933–1935 Dues:			
Members	24.00		
Corporates	5.00	29.00	
Total Dues			5 231.56
Dividends			565.22
Advertisements			2 905.00
Subscriptions			476.00
JOURNALS			55.00
Sundries			184.78
Total Receipts			9 525.56
There is due the Association:			
Advertisements		$502.00	
Standard Specifications		.25	
JOURNALS		6.25	
Half-tone		4.90	
Membership Certificate		1.50	
Boston Society of Civil Engineers' share of expenses for June 1934 Outing		39.55	554.45
Total			$10 080.01

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

Annual Report of the Treasurer.

September 1, 1933 to August 31, 1934.

The President and Members of the
New England Water Works Association:

I herewith submit my report as treasurer for the year ending August 31, 1934.

Receipts.

Initiation Fees	$ 108.00		
Dues	5 231.56		
	$5,339.56		
Less Refund	7.50	$5 332.06	
Interest		565.22	
From Publication of Journal:			
Advertisements	$2 905.00		
Subscriptions	476.00		
Sale of Journal	55.00		
Sale of Reprints	45.80		
Sale of Half-tones or Electros	13.23	3 495.03	
Miscellaneous:			
Tuition, Water Works School	$ 105.00		
Membership Lists	1.00		
Certificates of Membership	18.00		
Pipe Specifications	1.75	125.75	
Total Receipts			$ 9,518.06

Disbursements.

Publication of Journal:			
Printing	$3 102.91		
Plates	590.33		
Reporting	413.98		
Reprints	507.79		
Stationery and Postage	149.62		
Advertising Agent's Salary and Commission	100.00		
Editor's Salary	500.00		
Editor's Expense	9.86		
Drafting and Retyping	28.57		
Sundries	8.24	$5,411.30	
Office and General:			
Certificates of Membership	$ 14.25		
Engineering Society of New England	1 902.09		
Secretary's Salary	400.00		
Assistant Secretary's Salary	135.00		
Secretary's Expense	237.18		
Forward	$2 688.52	$5,411.30	$9,518.06

Amount Brought Forward	$2 688.52	$5 411.30	$9 518.06
Treasurer's Salary and Expense	122.13		
Printing, Postage and Stationery	159.81		
Office Rent	100.00		
Audit	50.00		
Taxes and Exchange	8.63		
Telephone	5.92		
Moving Expense	51.25		
Office Supplies and Sundries	82.91	3 269.17	
Meetings and Committees:			
Badges	$ 30.10		
Medal	10.01		
Dinner Guests	27.00		
Printing, Postage and Stationery	500.57		
Stereopticon	50.00		
Expenses re Convention	54.55		
Committee Expenses	24.15		
Share of Expense, Committee on Pipe	400.00		
Water Works School	267.50		
Sundries	20.25	1 384.13	
Total Disbursements for Current Purposes			$10 064.60
Excess of Current Disbursements over Receipts			$ 546.54
Furniture and Fixtures Purchased			1 113.50
Excess of Total Disbursements over Receipts			$ 1 660.04
Balance, General Cash, September 1, 1933			1 955.99
Balance, General Cash, August 31, 1934:			
Represented by Cash in Bank		$ 245.95	
Represented by Cash in Office		50.00	
			$ 295.95

Treasurer's Report.

Statement of Assets and Funds.

As at August 31, 1934.

Assets.

Cash in Banks, Invested Funds:		
City Five Cents Savings Bank, Haverhill, Mass.	$2 000.00	
Farmers and Mechanics Savings Bank, Framingham, Mass.	2 068.46	
Franklin Savings Bank, Boston, Mass.	2 000.00	
Haverhill Savings Bank, Haverhill, Mass.	2 000.00	
Home Savings Bank, Boston, Mass.	1 011.25	
Mechanics Savings Bank, Reading, Mass.	2 000.00	
Pentucket Savings Bank, Haverhill, Mass.	2 000.00	
Peoples Savings Bank, Worcester, Mass.	2 000.00	
Suffolk Savings Bank, Boston, Mass.	2 000.00	
Total Invested Cash		$17 079.71
General Fund:		
Cash, First National Bank of Boston	$ 245.95	
Cash in Office	50.00	
Total Cash, General Fund	$ 295.95	
Furniture and Fixtures	1 113.50	1 409.45
Total Assets		$18 489.16

Funds.

Invested Funds:		
Balance, September 1, 1933 and August 31, 1934		$17 079.71
General Fund:		
Balance, September 1, 1933	$2 790.99	
Less Accounts Receivable, August 31, 1933	835.00	
Adjusted Balance, September 1, 1933	$1 955.99	
Excess of Current Disbursements over Receipts	546.54	
Balance, August 31, 1934		1 409.45
Total Funds		$18 489.16

Note: — The above statement is prepared on a cash basis and does not reflect the following:

Accounts Receivable, Dues		$ 1 299.50
Due on Account of Advertising and Other Miscellaneous Charges		554.45
		$ 1 853 95
Accounts Payable		$ 50 10
Dues Received in Advance		29.00
		$79.10

Respectfully submitted,

(Signed) Leland G. Carlton, *Treasurer.*

SPRINGFIELD, September 14, 1934.

LELAND G. CARLTON, *Treasurer*,
New England Water Works Association,
Springfield, Massachusetts.

Dear Sir: In accordance with your request, we have made an examination of the accounts and records of the NEW ENGLAND WATER WORKS ASSOCIATION for the year ended August 31, 1934.

We submit herewith the following attached statements:

Exhibit A* Statement of Assets and Funds as at August 31, 1934.
Exhibit B* Statement of Receipts and Disbursements, General Fund, for the Year ended August 31, 1934.

We traced all recorded receipts to the depository bank, verified all bank accounts and petty cash fund as at August 31, 1934, and examined properly approved vouchers for all disbursements.

Very truly yours,
(Signed) SCOVELL, WELLINGTON & COMPANY.

*EDITOR'S NOTE: These exhibits are idental with the statements contained in the Treasurer's Report. They are on file in the office of the Secretary of the Association.

Annual Report of the Editor.

To the New England Water Works Association: The Editor submits herewith the following report for the year ending August 31, 1934.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed.

Table 1 is a statement of the material published.

Table 2 gives the receipts and expenditures for the year.

Table 3 is a comparison of the Journal for the past year with preceding years.

Size. The four issues contained 645 pages, of which 499 were text.

Cost. The gross cost of the Journal was $5 411.30, equivalent to $6.80 per member, and the net cost was $1 916.27, equivalent to $2.41 per member.

Reprints. Fifty reprints of each paper have been furnished to the author where desired.

Circulation. The present circulation of the Journal is:

Members, all grades	793
Subscribers	116
Exchanges	19
Total	928

(Journals *have been sent to all subscribers.*)

Respectfully submitted,

Gordon M. Fair, *Editor.*

Table 1.

Statement of Material in September and December, 1932, and March and June, 1933, Issues of the Journal of the New England Water Works Association.

Date.	Pages of.								
	Papers	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
September, 1932	100	24	124	0	36	5	0	160	17
December, 1932	112	10	122	8	38	5	0	160	29
March, 1933	117	5	122	0	36	5	0	158	33
June, 1933	128	3	131	0	36	5	0	167	40
Total	457	42	499	8	146	20	0	645	119

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF SEPTEMBER AND DECEMBER, 1933, AND MARCH AND JUNE, 1934, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.		*Expenditures.*	
Advertisements	$2 095.00	Advertising Agent's salary and commission	$ 100.00
Sale of JOURNALS	55.00	Editor's salary	500.00
Sale of reprints	45.80	Editor's expense	9.86
Subscriptions	476.00	Plates	590.33
	$3 495.03	Printing	3 102.91
		Reporting	413.98
		Reprints	507.79
		Drafting and Retyping	28.57
		Stationery and postage	149.62
Net cost of JOURNAL	1 916.27	Sundries	8.24
	$5 411.30		$5 411.30

TABLE 3.
COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Four Issues for Fiscal Year Ending Aug. 31,									
	1925.	1926.	1927.	1928.	1929.	1930.	1931.*	1932.	1933.	1934.
Average edition (copies printed)	1 100	1 100	1 100	1 138	1 200	1 350	1 260	1 200	1 125	1 100
Average membership	755	775	784	808	831	822	816	813	805	796
Circulation at end of year	873	906	916	955	993	980	955	957	930	928
Pages of text	421	523	492	528	507	570	410	437	420	499
Pages of text per 1 000 members	558	675	628	654	610	693	502	537	522	627
Total pages, all kinds	644	761	724	769	745	812	682	644	594	645
Total pages per 1 000 members	853	982	952	952	896	988	836	790	738	811
GROSS COST:										
Total	$5 272.91	$6 524.62	$5 839.36	$6 849.44	$6 740.87	$8 054.59	$6 135.33	$5 024.03	$4 712.16	$5 411.30
Per page	8.19	8.57	8.07	8.91	9.06	9.92	9.00	7.80	7.93	8.39
Per member	6.98	8.42	7.45	8.48	8.12	9.80	7.52	6.18	5.85	6.80
Per member per 1 000 pages	10.84	11.07	10.29	11.02	9.77	12.07	9.00	9.62	9.85	10.53
Per member per 1 000 pages text	16.58	16.10	15.13	16.06	16.01	17.19	18.34	14.30	13.94	13.62
NET COST:										
Total	$943.40	$2 040.28	$710.63	$1 716.25	$1 857.58	$3 664.76	$1,252.21	$1 121.20	$1 176.77	$1 916.27
Per page	1.46	2.68	.98	2.23	2.07	4.51	1.84	1.74	1.98	2.97
Per member	1.25	2.64	.91	2.12	2.24	4.46	1.53	1.38	1.46	2.41
Per member per 1 000 pages	1.94	3.47	1.26	2.76	2.50	5.49	2.24	2.14	2.46	3.73
Per member per 1 000 pages text	2.97	5.05	1.85	4.02	4.41	7.82	3.73	3.16	3.48	4.83

*Including Comprehensive Index, 1882 to 1930.

Progress Report of Committee on Amendment of the Constitution of the New England Water Works Association.

August 16, 1934.

To the Executive Committee
New England Water Works Association.

Gentlemen: The Committee on Amendment of the Constitution of the New England Water Works Association respectfully submits the following report.

In accordance with your request, the Committee has examined the constitution of the New England Water Works Association as amended to revised form January 9, 1923, and finds that there are several articles in this constitution which should be carefully considered with the possible view of amendment.

Membership.

Article II, Section 2 provides —

A Member shall be an officer or employee of a public or private water works, an engineer, chemist, or other person qualified to aid or interested in the advancement of knowledge relating to water works.

while Section 6 provides —

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

It would appear to the Committee that these two sections are somewhat conflicting inasmuch as the man actually engaged in water works practice may either be eligible for membership as a "Member" or as an "Associate." The Committee realizes that the matter of distinction between a Member and an Associate Member is one which has received careful consideration in past years by the Association, and under the circumstances the Committee requests further time before offering a possible amendment to Article II on Membership. The Committee in this regard also respectfully requests an expression of opinion of the membership of the society.

Meetings.

An examination of Article VIII of the constitution concerning Meetings shows that Section 2 must, in the opinion of the Committee, be amended in order to provide accommodations for meetings at the Statler Building during the coming year. Accordingly, the Committee recommends that Section 2 of this article be amended as follows:

Section 2. In addition to the annual convention, business meetings shall be held in Boston, on the third Thursday of the months of November, December, January, February and March.

By vote of the Executive Committee, and after due notice thereof shall have been given the members, additional business meetings may be held in

or outside of Boston but at least one extra meeting each year shall be held in a New England state other than Massachusetts.

By vote of the Executive Committee, the date of all, or any, business meetings in any one year may be changed to meet unforeseen contingencies.

Award of Medal for Most Meritorious Paper Presented by Water Works Official.

With a view of encouraging superintendents and other water works officials to contribute more generously in the matter of practical papers on the subject of water supply, the Committee is of the opinion that the Executive Committee should consider the establishment by the New England Water Works Association of an award for the most meritorious paper submitted during the year by water works superintendents or other water works officials.

The Committee wishes this report to be considered as a progress report only and recommends that this or a similar committee be re-appointed to further consider matters of amendment of the constitution.

Respectfully submitted,

ROGER W. ESTY,
SAMUEL E. KILLAM,
PERCY R. SANDERS,
CHARLES W. SHERMAN,
ARTHUR D. WESTON, *Chairman.*